THE BUILDING OF THE ALPS

T. G. BONNEY

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From a photo by] [*Mr. J. J. Lister, F.R.S.*

I. CRAGS OF THE GALENSTOCK.

Frontispiece.

THE BUILDING OF THE ALPS

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WITH 48 ILLUSTRATIONS

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PREFACE

THIS book is to some extent written on the lines of one entitled "The Alpine Regions of Switzerland and the Neighbouring Countries," published in 1868, which has long been out of print. But it dwells much more on the physical and geological history of the chain than at that time was possible, and it embodies the results of special work on this subject in which I became engaged during the next decade. It deals with several controversial questions, on some of which I have not hesitated to express opinions adverse to those maintained by other workers, most of whom can be in a part of the Alps without leaving their fatherland. My excuse for this audacity, as some may think it, must be that, as explained in Appendix I, I have done what I could to see things for myself in the years, numbering more than forty, during which Alpine climbing has gradually yielded place to Alpine geology.

I have tried, as far as possible, to avoid technical terms, though these are sometimes necessary, and I have not attempted minute research in Alpine literature, now become very large, but I have endeavoured to write from the point of view of one who is a lover of the Alps, is somewhat of a geologist, and a little of a naturalist. I cannot hope to have avoided mistakes; for, if we are fallible mortals even in the days of our youth, sad experience teaches us that, after a certain age, accuracy is very apt to diminish as our years increase, and the changes that have been made in the spelling of names and in the heights assigned to "Peaks and Passes" are very confusing to the memory. Such mistakes would have been more numerous were it not for the kindness of my friend Mr. R. H. Rastall, F.G.S., Fellow of Christ's College in this University, who has read the proofs and given me the benefit of his criticisms and corrections. I am also deeply indebted to Dr. W. A. B. Coolidge, whose topographical and historical knowledge of the Alps is unsurpassed, for permitting me to use some of the information embodied in his masterly work, "The Alps in Nature and History. My thanks also are heartily tendered to those who, as mentioned in detail in Appendix II, have supplied me with photographs or permitted me to use illustrations which have already appeared in other works.

It may be that I have looked my last on the Alps. The irksomeness of railway journeys is greater, the miles are longer, and the mountains steeper than they used to be, but I owe them a debt of gratitude for gifts of health and strength to body and mind, and for many a happy hour.

CAMBRIDGE, *April*, 1912.

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For permission to use Figures 1–3, 5, 11–13 I have to thank the Council of the Geological Society of London; for Figure 4 (from Lake and Rastall's "Text-book of Geology"), Mr. Edward Arnold; for Figures 6–10, 14–16 (woodcuts by the late Edward Whymper illustrating "The Alpine Regions"), Messrs. G. Bell and Sons, Ltd.

The Building of the Alps

CHAPTER I

GEOGRAPHICAL DISTRIBUTION OF ALPINE ROCKS

THE rocks composing the Alps, like those of most important mountain chains, can be divided into two great groups—the one obviously sedimentary, the other of more uncertain origin. The former may be subdivided into a series of limestones and shales or slates, which have partaken of the two great earth movements that gave birth to the existing chain, and a set of pebble beds and rather soft sandstones, which have shared only in one of them. The latter group is also capable of subdivision, but is throughout crystalline in structure. Some of its members have undoubtedly cooled down from a state of fusion; others must be sediments, the constituents of which have undergone important changes; while of others the origin is still a matter of dispute, to which we must presently refer. Such are the gneisses and schists,[1]

[1] In compliance with the principle enunciated by the late J. B. Jukes, I invariably restrict the term "schist" to foliated rocks, *i.e.*, those which, whatever their origin, are in a crystalline condition and exhibit a parallel ordering of their constituents. The lax use of the term "schist" by some English geologists, of "*schiste*" by French, and "*schiefer*" by German has, in my opinion, been a fruitful source of error.

all of which exhibit more or less clearly the structure called foliation; namely, a roughly parallel arrangement of the more conspicuous minerals, especially of those which, like mica, are rather leaf-like in form.

The higher peaks and more prominent ridges—the backbones of the greater ranges—consist of crystalline rocks; for even where these may not be actually visible, there is always good reason for believing them to be the foundations upon which the sedimentary rocks are resting. Only once do the latter attain an elevation of 13,000 feet—in the limestone peak of the Eiger, which slightly exceeds that altitude—and very few rise above 12,000 feet; the majority of the more conspicuous of these summits ranging between that height and 10,000 feet. But the culminating summits of Dauphiné, the Tarentaise, and the Maurienne, of the Pennines, from Mont Blanc to their eastern boundary, of the Oberland, the Bernina, and the Central Tyrol, all consist of crystalline rocks. They rise above 15,000 feet in Mont Blanc and Monte Rosa; in nine other peaks they exceed 14,000 feet, while quite a large number surpass the highest limit of the sedimentaries.

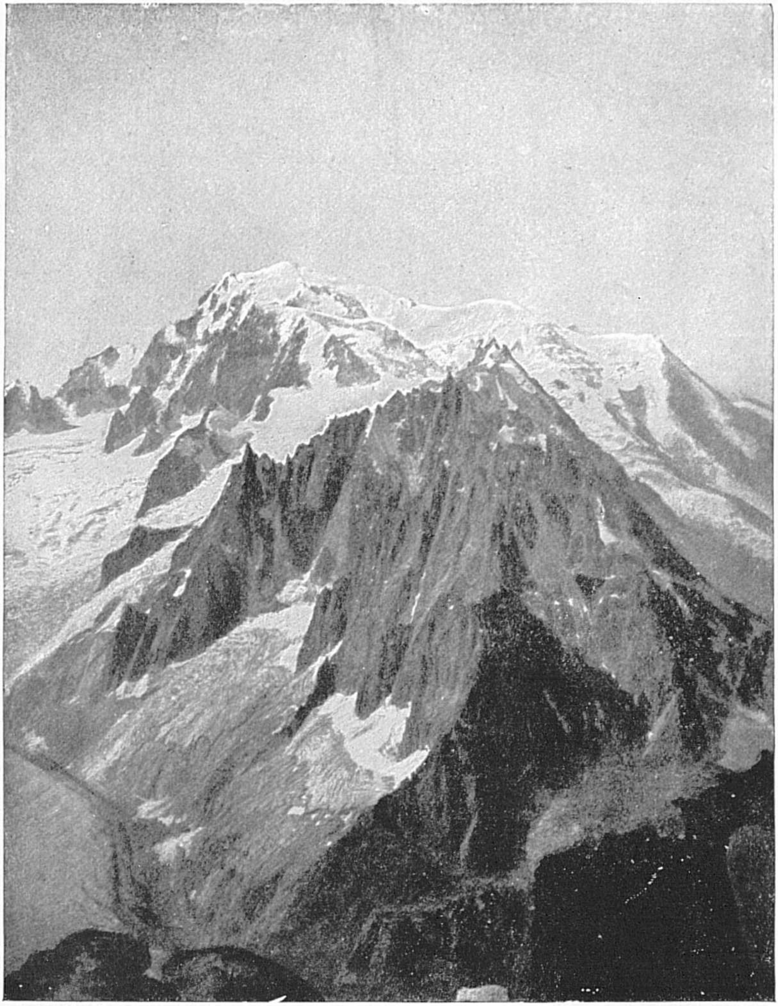
We must now discuss at more length the origin of these crystalline rocks, and their geological age—namely, whether (with the exception of a few comparatively small intrusions of ordinary igneous rocks) all of them are older than the sedimentary groups, or whether they may sometimes represent members of the latter, so much altered in aspect and constitution as to be practically unrecognisable. At first these crystalline rocks, in most of the great ranges, appear, when allowance is made for the results of later disturbances, to exhibit a more or less progressive change and an increasing definition of character. For example, the central peaks of the Dauphiné Alps, the Mont Blanc range, with some other parts of the Pennines, and of the Oberland, consist of a rock generally not very conspicuously foliated and bearing considerable resemblance to a granite. It is usually rather coarse in texture, and sometimes also porphyritic in structure, containing large crystals of felspar, which, however, are generally more rounded in outline than in a normal granite. By the earlier geologists this was supposed to be a rock which had not cooled down from a state of ordinary fusion, but had been precipitated from a menstruum—a kind of world-porridge—with which our globe was surrounded, when the temperature of the incandescent mass had fallen low enough to allow water to condense upon its surface.[1] From this menstruum, first the gneisses, then the other foliated rocks, were believed to have been deposited; these, as its temperature fell, gradually presenting more resemblance to ordinary sediments. To the group of granitoid gneisses the name of protogine, or "first-born," was given. This, as we shall presently see, is a misnomer, but that the group often occupies a central position in the range is a fact. In apparent succession to it, we find another large group of gneisses, which, though frequently composed of the same minerals

[1] They also supposed that it differed from a granite in the substitution of talc for mica as its third principal mineral. It has, however, long been known that this is not talc, but only an altered form of mica, so that there is no real difference in the mineral composition of the two rocks.

as ordinary granite, contain them in varying proportions, are often rather conspicuously foliated, and exhibit more or less of a banded structure. Occasionally they become so micaceous as to deserve the name of mica-schists. In some places they seem to pass upwards into rather saccharoidal and friable gneisses, with well-marked alternating bands, the one rich in quartz with felspar, the other in mica (mostly dark); or into gneisses where, as at the St. Gotthard, the rock is rather stronger, the banding less marked, but red garnets and elongated hornblendes are conspicuous. Last of all comes a very variable group of schists, often conspicuously foliated. In these, beds of mica-schist, quartz-schist, and crystalline limestone alternate, just like shales, sandstones and limestones among the ordinary sedimentaries, and exhibit, as in the latter case, a number of transitional forms. With these are associated, but more sporadically, serpentines, and a quantity of peculiar hornblendic and chloritic rocks, most, if not all of which, were once dolerites or basalts—the *Grünerschiefer*, or "green schists," of Continental geologists. Rocks of a generally similar origin may also be found among the first-named group, but they are generally coarser in structure, and more like ordinary diorites, from which they chiefly differ in showing some amount of foliation.

Before discussing this apparent succession, we must enlarge a little on the origin of foliation, which, as has been said, may or may not be associated with a distinctly alternating mineral banding. Most geologists now maintain that these structures have not always had the same origin. They may be the result of movements—a kind of flow—in a molten magma, which, however, had already either separated into portions differing to some extent in chemical composition, or had begun to crystallize. Thus the former is analogous to the flow structure which is often exhibited by certain lavas, and the latter is occasionally found in some coarsely crystalline rocks, which were undoubtedly once in a molten condition. But gneisses may also be the result of movements of another kind. Pressure produces on rocks which were once deposited as clays a structure called cleavage, that is, the property of splitting along planes, which have no necessary connection with their original bedding. That has long been known, and this mechanical rearrangement is sometimes accompanied by a certain amount of chemical change, which is shown by the development of sundry new minerals, often very minute but in large quantities. Of these a mica is the most common, and where it is abundant the slate assumes a peculiar silky lustre, and is called a phyllite. It is, in fact, an infantine mica-schist. But pressure also has notable effects on crystalline rocks, by producing a rude cleavage and a development of secondary minerals, chiefly on its surface. This also is a kind of foliation, but as it is a comparatively modern discovery, and there is now perhaps some tendency to exaggerate the effects of pressure-metamorphism, or dynamo-metamorphism as some call it, we may avert future misconceptions by giving a description of the process. Let us take, as an example, a porphyritic granite, such as might be found in parts of Devonshire or Cornwall, and suppose it to be exposed to a pressure increasing gradually in strength. First the angles of these isolated felspar crystals are broken off, while the smaller ones in the matrix are more or less crushed. So also is the quartz, and the mica is often torn. A rude cleavage is thus produced, as it might be in a quartz-felspar grit; and as this structure gives easy access to water, new minerals are developed, the comminuted felspar breaking up into a potash or soda mica and free quartz, both much smaller than those in the original rock. Thus the ultimate result of the pressure is a foliation, and the granite has become a gneiss. The more or less rectangular porphyritic felspar crystals, when present, assume an oval outline, something like eyes, from which German geologists have called this rock an augen-gneiss (eyed-gneiss.) As the pressure is continued these eyes are gradually flattened and elongated, the other minerals are comminuted and drawn out, especially if, as is very commonly the case, the crushing is associated with a certain amount of shearing, so that a fine-grained, linear-streaked gneiss is formed, as if the rock had once been stratified. In the last stage of all, often to be found in the neighbourhood of a fault, the felspar is replaced by mica and minute quartz, and the gneiss is converted into a fine-grained fissile mica-schist. Basic rocks, such as dolerite and basalt, are also rendered more or less fissile and undergo analogous changes,[1] but here the augitic

[1] I think, however, they resist rather better than the granitic rocks, and that the only change (which may be anterior to any crushing) may be the replacement of the augitic by a hornblendic constituent, and I have little doubt that many granular hornblende schists owe their structure to movements anterior, not posterior, to consolidation.



From a photo by] [*Mr. Samuel Turner, F.R.G.S.*

2. MONT BLANC AND AIGUILLES DES CHARMOZ.

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constituent is almost invariably changed into a needle-like form of hornblende. The felspar, however, seems to be less readily converted into white mica and quartz, and either remains unaltered or is replaced by a new felspar rather different in chemical composition. These features, which can be observed in rocks certainly intrusive, also characterise the *Grüner-schiefer*, the larger masses of which, when mapped, often suggest by their outlines a similar origin.[1]

Pressure also produces a somewhat similar effect on the more banded gneisses and the schists. The crushing, however, is often not quite so marked as in the rocks we have been discussing. A banded gneiss often retains that structure, and if the direction of the pressure happens, as is not seldom the case, to have been at right-angles to it, the rock simply becomes rather more easily broken in the direction of the bands, owing to the development along their surface of a filmy white mica. If, however, the line of pressure makes a high angle with the normal to the bands, these have been puckered and folded, and the rock at last has been affected by a cleavage on the surface of which the usual secondary mica is produced. Similar results are manifest in the various schists of crystalline origin. In these the original foliation, due to stratification, either is intensified or becomes puckered, and a cleavage foliation is set up. So far is this carried in some cases, where the rock is not very strongly banded and is rather liable to fracture, that the original structures are

[1] It is, of course, possible that locally they may have been originally basaltic lavas and tuffs.

effaced and the rock splits into plates hardly thicker than stout millboard.

All the members of this group had assumed a crystalline condition, were metamorphic rocks in the strictest sense of that term, long before the effects just mentioned were produced by the crumpling of the earth's crust into mountain ranges. In their metamorphosis pressure, due to the weight of overlying strata, was no doubt one factor; water was another; but a long-continued elevation of temperature was, we may reasonably believe, even more important. Their combined action set up molecular rearrangements; in many cases it developed new minerals: it converted the muddy sand into a micaceous quartz-schist; it gave birth locally to garnets, staurolites, kyanites, and other minerals, so that the original constituents can be distinguished only in one or two exceptional cases where actual pebbles have been present.

At one time most geologists supposed that the gneisses were also metamorphosed sediments, and some of them even went so far as to maintain that granite itself was not a true igneous rock, but the last stage of all in the process of metamorphism. That, however, is now relegated to the limbo of discarded hypotheses, though whether it will be allowed to rest there in peace is perhaps doubtful. Certain controversies, not in geology only, have a habit of recrudescence, and as an element of truth is sometimes present even in such hypotheses, it makes them sufficiently plausible to be attractive to the unwary. Still, at the present moment, we cannot be certain about the origin of all gneisses. A large number undoubtedly were once granitic rocks, in some of which the foliation is original, the result of fluxional movements; in others it has been acquired by subsequent pressure. That is undoubtedly the history of the Alpine augen-gneiss, for in places where examination of junctions is possible, its masses are clearly intrusive in the associated gneisses or schists. The ordinary Alpine gneisses—those generally fairly strong, not very conspicuously banded, or exhibiting any very notable structure—a great thickness of which often appears to overlie the augen-gneisses or protogines—may also be, at any rate in most cases, igneous rocks, though earlier than them; but when we come to those which are more banded, a little finer in grain and rather more friable, it is exceedingly difficult, in the present state of knowledge, to arrive at a conclusion. Their structure may be due, as in some of the Laurentian rocks of Canada and the Lewisian in North-west Britain, to fluxional movements, or it may be explained on the hypothesis of a *lit par lit injection*,[1] though I think this could only occur under special circumstances and over a rather restricted area, while such gneisses often extend for a considerable distance. Again, they may be metamorphosed sediments, like the group overlying them. The alternation of bands, differing considerably in mineral characters—much resembles that of the quartzose and micaceous bands in some of the schists,[2] and as in their case we need but assume

[1] When a molten rock has forced itself (like a paper-knife between the leaves of a book) along the foliation planes of a schist.

[2] *E.g.*, in the Val Piora or on the Nufenen Pass.

that the strata were depressed to a sufficient distance beneath the earth's crust to bring them into a zone of an adequately high temperature.[1] One difficulty, however, at present exists: that, so far as I know, we do not find examples of such gneisses interstratified among schists which were once sediments, and that felspar of secondary origin seems to be infrequent among either these or strata rendered crystalline by contact action. Neither have fragments of another rock, like the pebbles in the quartz-schists of the Einfischthal, ever been proved to exist, so far as I know, in a true gneiss. I have examined more than one asserted case, and in each the evidence has broken down.[2]

Between these crystalline rocks, whether gneisses or schists, and the earliest of the sedimentary deposits, is a great break, and even the oldest of the latter, under the most favourable circumstances, have not advanced in metamorphism beyond the stage of

[1] A good many of the ordinary rock-forming minerals actually melt at temperatures from 1,100° C. to 1,300° C., but in the presence of water they would dissolve at a much lower temperature. Very possibly one not much above 100° C. would suffice, given time and pressure enough for the changes required in the metamorphic rocks. This would now be reached nine or ten thousand feet below the surface, and at a considerably less depth at a certain early stage in the earth's history.

[2] I do not deny the possibility of some gneisses being metamorphosed sediments; nay, I think this would be the easier explanation in certain cases; but, after having been brought up in that creed, and having taught it until I began to investigate the question for myself, I have been vainly searching—now for not a few years—for a case which was conclusive. The well-known pebbly upper gneiss at Obermittweida is not really a gneiss, and somewhat similar specimens, from the southern Highlands, hint at the existence of a break between the two sets of rocks.

phyllite.[1] The earlier sedimentaries, representing more than one period in the Palæozoic era, are rather sporadic and limited in distribution. Rocks assigned to the Silurian and Devonian systems have been identified in the eastern part of the Northern Tyrol; those representing the Carboniferous are more widely distributed. They occur, for instance, in more than one district of the Eastern Alps, are probably infolded locally in the valley of the Rhone from Brieg to Sion, and may be traced from that river near Saxon in a south-westerly direction through the Tarentaise and Maurienne to the neighbourhood of Briançon; a narrower strip, sharply infolded, crosses the same valley near Vernayaz and may be traced, though with many breaks, to the west of Chamonix, through the French Alps across the Romanche towards the Drac. The formation consists of slaty rocks with grits and breccias, as may be seen between Vernayaz and Salvan, and includes occasional seams of anthracite. Limestones are rare, but one which, at first sight, resembles a marble belonging to the crystalline series, is quarried on the left bank of the Rhone, less than a league from Saxon.[2] Slates are worked, and breccias are well exposed between Vernayaz and Salvan. Fine specimens of fossil ferns have been found not far from the Col d'Anterne,[3] but, as a rule, organic remains are few or absent. The

[1] The reason for this statement, which is repudiated by some geologists, can be more conveniently given in a later part of this chapter.

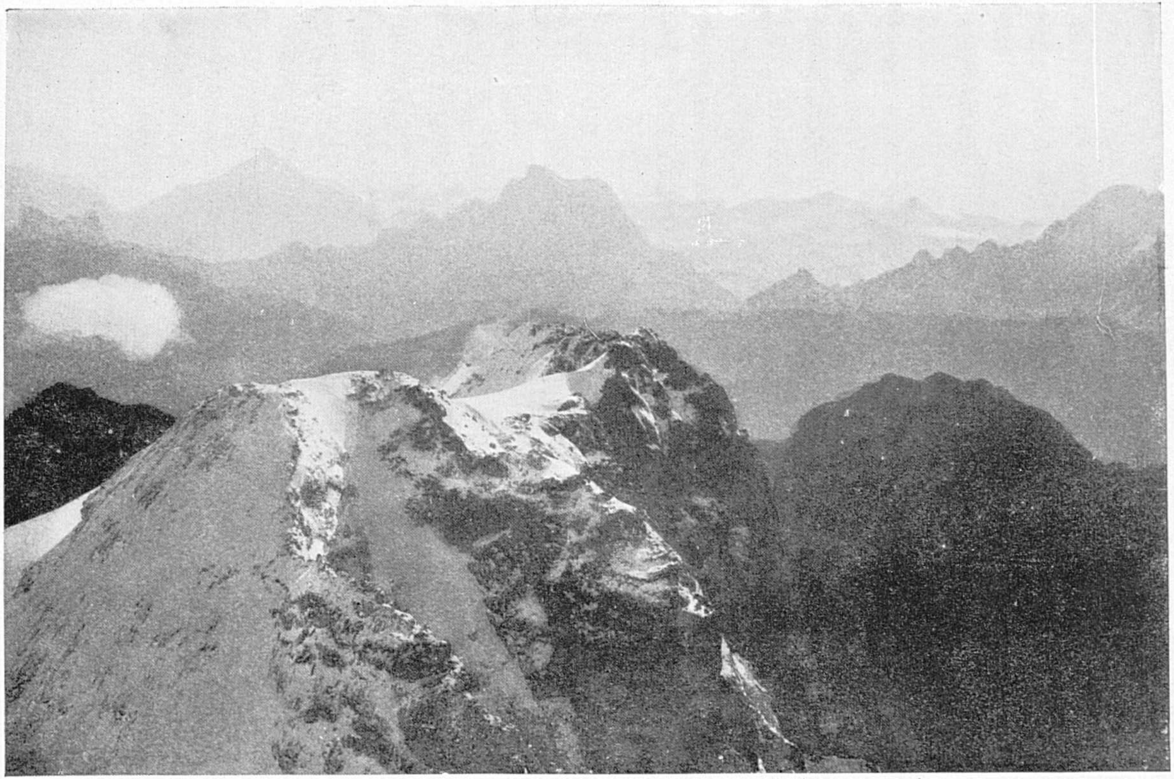
[2] The Pontiskalk, a less pure subcrystalline limestone crossed on the ascent from Sierre to the Einfischhal, may also belong to this period.

[3] A. Wills, "The Eagle's Nest," ch. vii, 1860.

Permian period is represented in the south-eastern Alps by some important masses of igneous rocks, largely volcanic, and more or less red in colour, which can be more conveniently noticed in the next chapter; others, on a smaller scale, occur on the southern margin of the Alps near the Piedmontese Plain in the neighbourhood of Lugano and Arona, and elsewhere sundry isolated outcrops of igneous rocks are believed to belong to the same period. With these are associated some sedimentary rocks, generally of limited extent, the most noteworthy of which are a red sandstone, locally used for building purposes,[1] and a variable impure limestone, called Verrucano, which is sometimes crowded with angular fragments of the older rocks.

But the Mesozoic or Secondary rocks are far more extensively developed, and though sometimes interrupted by the crystalline, as we have already described, may be traced throughout the whole length of the Alpine chain. From its eastern extremity to the neighbourhood of the Upper Inn Valley they are well displayed on both sides of the central crystalline axis, but farther west a complication appears in the structure of the chain, and the sedimentary cover gradually becomes more ragged on the southern side, until in the neighbourhood of the Sesia it altogether disappears. Of these Secondary rocks the lowest system—the Trias—is the most inconstant. In the Eastern Alps it is represented by a thick series, mostly limestones or dolomites, with which, in the south, some important igneous rocks are associated, to the details of which we shall return; but these do not occur on the northern side of the central

[1] The *Grödner Sandstein*, regarded by some as Lower Trias.



From a photo by] [*Signor Vittorio Sella, Biella.*

3. DOLOMITE PEAKS, FROM THE MARMOLATA.

To face p. 22.

axis. Two of the dolomitic masses are of great importance, and they give rise to some of the grandest scenery in the south-eastern Tyrol. The lower one, the Schlern, which is sometimes 3,000 feet in thickness, but the less widely extended, represents the upper part of the Muschelkalk (a group missing in Britain) and the lowest of the Keuper. Beds of this age occur, but with less lithological uniformity, also on the northern face of the Alps. The other, or upper mass, is called the Dachstein dolomite. This is found in both the northern and southern ranges, and is assigned to the epoch of passage from the Keuper (or Upper Trias) into the lower part of the Jurassic system.[1] As we proceed westward, the Triassic deposits die away, and are often represented between the Upper Rhine and Rhone by a limestone, which is frequently soft, friable, and not seldom associated with gypsum, is generally of no great thickness, and sometimes altogether vanishes.

The Jurassic system is represented by limestones associated with shales or slates. Some of the former are as thick, strong, and compact as the Carboniferous limestones of England and Ireland, and to them we are indebted for some of the most beautiful scenery of the Oberland.[2] They extend across the Rhone into Savoy, and continue through the French Alps to the extreme south, often giving rise to features hardly less impressive than in the Oberland. Important lime-

[1] Valuable deposits of salt occur among the Triassic beds of the Northern Tyrol, and more locally in Switzerland (at Bex) and in the Maurienne (at Moutiers).

[2] Some of these make excellent building-stone, and are largely employed for masonry and ornamental purposes in the larger towns.

stones are also associated with the Neocomian (sometimes called the Lower Cretaceous) system, and with the Cretaceous (or Upper Cretaceous), though in the latter they are often less pure. In the Alps the marked break which in Britain separates the Chalk (the uppermost of the Secondary deposits) from the bottom of the Eocene (the earliest of the Tertiaries) cannot be detected, and the latter do not include any limestones of importance. But we find, especially in the Central and Western Alps, a thick, more or less slaty deposit, called the Flysch, the scenery of which, owing to its physical characters, is usually less bold than in the underlying Secondaries. In this rock fossils are generally far from common, but it contains some curious breccias, to which we shall again refer, and it may be traced through the northern part of the chain from one end to the other. It must represent an epoch characterised by similar conditions of deposit, and it is believed by those who have specially studied it to belong, in the Central and Western Alps, to the Eocene;[1] though it may extend, towards the south, rather above the end of this period, while in the Eastern Alps it may have begun during the Cretaceous.

In Oligocene[2] times the making of the Alps, as we know them, began. Lateral thrusts, apparently acting outwards from a Mediterranean which extended over a much larger area than the present sea,

[1] Here it overlies, or is associated with, strata containing *Nummulites complanatus* and other well-known Eocene fossils.

[2] This period, the utility of which is not universally acknowledged, includes, speaking in general terms, the Upper Eocene and Lower Miocene of the older geologists.

crumpled up the earth's crust on the site of the Alps, and raised a mountain chain, which, so far as we can judge, was developed and uplifted with comparative rapidity. This chain must have come into existence even before the end of the Oligocene period: it underwent denudation on a vast scale during the Miocene. Its rivers swept down to the marginal lowlands, on which a shallow sea for a time lingered, enormous masses of gravel and sand. The former were thrown down in huge banks, spreading outwards from the mouths of valleys, which corresponded in the main with those still followed by the principal rivers, and the latter are seen in the great masses of sandstone which, with an occasional seam of gravel or more frequent band of shale, constitute the so-called lowlands on the northern (to some extent also on the southern) fringe of the Alpine regions, where they furnish a building-stone, of a pleasant grey colour, easily worked, and fairly durable, which is largely employed in the principal towns. The gravels, the so-called Nagelfluhe, are occasionally fully a mile in thickness, and have subsequently been upraised, until in the Rigi and the Speer they attain some 6,000 feet above sea-level.

Towards the close of the Miocene period another epoch of mountain-making began, and the process was continued into the Pliocene. No deposits of importance, representing the latter period, can be identified within the limits of the chain. To make acquaintance with these we must carry our researches into the lowlands, but a morainic deposit overlain by a coarse gravel may perhaps be referred to its latest stages.

From the end of the second uplift the work of sculpture has far exceeded that of deposition; the latter has been limited to the larger valleys, and in most cases its results are of a superficial character—screes and moraines, mud-streams and gravels, most of them directly or indirectly due to the action of glaciers. These results, which offer many problems of great interest and importance, can be more conveniently noticed when we come to deal with the question of the growth and sculpture of the Alps.

CHAPTER II

MATERIALS OF THE ALPS, THEIR NATURE AND ORIGIN

THE crystalline rocks of the Alps, as I have stated in the last chapter, are commonly divisible into three groups. One, which at first sight often appears to be the most ancient, consists of more or less coarse granitoid rocks, not seldom exhibiting a porphyritic structure, the augen-gneisses or protogines. They form the central part of the Mont Blanc and the Oberland ranges; they appear frequently in the Pennines, the Arolla gneiss being probably one of them. They occur in the Lepontine Alps; for the porphyritic rock of the Lukmanier Pass, the Fibbia gneiss at the summit of the St. Gotthard, and the granite of the Pizzo Rotondo, may be associated with these. They are also found in the Tyrol, and a variety forms much of the Pelvoux *massif* of Dauphiné, which, however, so far as I have seen, is not porphyritic. There are, however, some granites in the Alps, like the masses near Pallanza and Baveno on the Lago Maggiore, which, as we shall presently see, may be of later date. Those coarse granitoid rocks, however, are not the most ancient, for in many cases representatives of them are intrusive in the other two crystalline groups, and must therefore be of later date. The former of these groups consists of strong gneisses, sometimes passing into mica-schists of corresponding character. They differ in some respects from the gneisses so characteristic of the Laurentians of Canada, examples of which may also be found in the Outer Hebrides, and on the north-west coast of Scotland. Rocks of the latter type occur in the Alps, so far as I have seen, only on the Velber Tauern Pass to the east of the Gross Venediger. A similar type is exposed at the rapids of the Rhine at Laufenburg, but this is connected with the Black Forest, where such gneisses are common, rather than with the Alpine region. These strong gneisses and mica-schists, whatever be their origin, are apparently the oldest rocks in the Alpine chain. It is possible, nay probable, that many of them are really igneous in origin, and owe their banded structure to fluxional movements during crystallization, and it is also possible that this process occurred at an early stage in the consolidation of the globe. When the temperature of its surface was well above the boiling-point of water, the ocean would be a vapour instead of a fluid, and the atmospheric pressure would be equal to that of about 4,000 feet of average rock. But under these circumstances the melting-point of such material would be reached at a depth of not more than four miles, instead of at least twenty, and a rock might remain mobile to within a moderate distance of the surface; not much more below it than Mont Blanc is now above the sea; so that rupture of the overlying crust and effusion from beneath it would be considerably more easy. At a somewhat later date, when water could accumulate on that crust and begin its denuding work, chemical action both of solution and of precipitation would be more rapid; while at depths but little below that which has been reached in mines or borings, we should have a temperature of at least 400° F. That would greatly facilitate the metamorphism of sediments, and might even affect the nature of the minerals produced. Under these circumstances felspar, which is a rare constituent of the obviously stratified schists or of contact metamorphism,[1] might be readily produced, and those peculiar well-banded and often friable gneisses, which seem more suggestive of the bedding of sediments than the fluxion structure of an igneous rock, might have this origin. A crystalline limestone must once have been either a precipitate or an accumulation of organisms, and such a rock occurs in ordinary gneissic regions, both in the Oberwald, Sweden, and Canada, and it may occur in the Alps, but, as it happens, I have not there seen a satisfactory instance of its association with rocks older than the upper group, that of the crystalline schists, the sedimentary origin of which, allowing for some occasional intrusive rocks, cannot, I think, be doubted.

These schists were deposited, as I believe, on an irregular surface (*i.e.*, one which had undergone considerable denudation) of the older or second group

[1] From an ordinary clay mica would be more easily produced than felspar, as the following theoretical proportions indicate. Taking alumina as the unit, orthoclase felspar requires 3·51 of silica and ·91 of potash; but mica (muscovite) 1·17 of silica and ·30 of potash. In biotite the proportions of these two are about 2·3 and ·5. The destruction of felspar to form clay means the removal of silica and potash, so that it becomes easier to make a mica than to reconstitute the felspar.

of rocks, because sometimes no small thickness of gneisses of a different kind, especially of those which are suggestive of a sedimentary origin, intervenes between the former and the latter, examples of which may be found occasionally in the Pennines, in the St. Gotthard district, and in more than one part of the Tyrol, not to mention other places. But more commonly the stratified schists follow in close succession to the lower gneisses. At the base of the former, at any rate in the Pennine range south of the Rhone valley, a quartz-schist often comes, which, in the Einfischthal, is sometimes distinctly pebbly, and elsewhere contains, here and there, felspars very like original fragments. Crystalline limestones or dolomites, are frequent, which pass into the calc-mica schists, occurring in a rather lenticular fashion, as might be expected. The latter exhibit many variations, not seldom becoming a lead-coloured mica-schist with but little calcite, which in places is so dark as to suggest the presence of graphite. This variety often contains fairly large, though rather impure, dark garnets. These very micaceous schists may be traced, with little interruption, throughout the Alpine chain. They are the *Graue-schiefer kalkhaltig* of the Swiss geological survey and the *Thon-schiefer* with the *Kalk-glimmer-schiefer* of Von Hauer's map of the Eastern Alps. Staurolite-schist is sometimes found, a variety with fine examples of that mineral occurring near the north-east end of the Lago Ritom, and another, which also contains large specimens of kyanite, on the Pizzo Forno, near the Campolungo Pass.

A silvery rather fissile schist, largely composed of a white mica, with a certain amount of the brown species, occurs at several localities between the Gries and the Lukmanier Passes. By some Swiss geologists this is termed disthene-schist; but as that mineral (kyanite), though present, is inconspicuous, I prefer to call it "two-mica schist," and shall refer to it under that name on a future page; for as we shall see, its evidence is often of great value in determining an important theoretical question. Green schists, the *Grüner-schiefer* of the Swiss geologists, the *Talk-und-chlorit-schiefer* of Von Hauer, are to be found, though to a variable amount, in almost every part of the Alps. This rock is rather scarce, so far as I know, in the Dauphiné district, but is more abundant in the Cottian; thence it may be traced through the Maurienne and Tarentaise to the Graians, where it is anything but rare. It abounds in the Pennines, and may be followed, though with some interruption, along the Lepontines, but is not common, so far as my wanderings have extended, in the Oberland or the Rhætian Alps. East of the Inn Valley it again becomes commoner, and is well developed in the central range of the Tyrol. Some varieties are fairly granular and moderately strong rocks, occasionally rather distinctly banded; while others are fine-grained, schistose (sometimes almost fissile), and often rather paler in colour than the others. All of them contain a fair amount of chlorite and hornblende, the latter being often a minute acicular variety, with quartz and some felspars.[1] It is often probable, and not seldom certain, that these green schists were originally intrusive basalts or fine-grained

[1] Some of these are later in date than the crushing from which the rock has suffered.

dolerites, the structure and mineral composition of which has been altered by subsequent pressure; but it would be, perhaps, rash to deny the possibility of some having been tuffs of like composition.[1] Coarser hornblendic rocks—true diorites—also occur; some of normal character, as locally in the Bernina group and in a broad band of hornblendic rocks which extends along the southern margin of the Alps from west of Ivrea to near Locarno; others almost picrites, as above Hospenthal on the St. Gotthard and north of Pontresina, none of them of any extent; others containing a fair amount of quartz, like the well-known tonalite of the Adamello *massif*. These green schists in most cases are closely associated with the calc-mica schist group, though in some they break through or into the gneiss, instances of which may be seen on the Mittaghorn near Saas and on the Bernina Pass, while the southern zone of coarser rock is generally, if not always, associated with gneisses. The green schists forming the ice-worn mounds at the foot of the Allalin Glacier and near the lower end of the Mattmark See, are traversed by many thin veins of a light-coloured rather fine-grained granite, which appears to have been at a high temperature when it was injected, because it has locally melted down small quantities of the green schist, thus producing interesting examples, on a small scale, of a streaky biotite gneiss.[2] These may be offshoots from the magma which has elsewhere been the origin of the "augen-gneisses," but I

[1] I thought in 1888 that I found a passage (in the valley above Mairhofen) of a green schist into a calc-mica schist (*Quart. Jour. Geol. Soc.*, 1889, p. 87), but should like to examine the rocks again in the light of wider experience.

[2] *Geol. Mag.*, 1894, p. 114.

do not remember to have met with an example of the latter rock actually intrusive in the green schist, though it is occasionally in the calc-mica schist.

One more rock group, originally igneous and among the later intrusions, must be noticed before quitting these ancient crystallines. This consists of peridotites, or olivine rocks, which have now almost always been altered by hydration to serpentines. Of these there are, speaking in general terms, two varieties; the one being a bastite-serpentine (once an olivine-enstatite rock) like that forming some considerable masses in the Apennines, and much of that at the Lizard; the other an antigorite-serpentine, which often, though not invariably, has come from an augite-olivine rock.[1] The former, so far as my experience goes, is the rarer. It occurs about the Mont Genèvre and the Col de Sestrières, rather abundantly on the Julier road, east of Tiefenkastel (where, as at the Lizard and in Ayrshire, it is cut by a fairly coarse gabbro), and sporadically in a few other localities. The antigorite-serpentine is much the more abundant. I have met with it from the neighbourhood of Monte Viso in the south to that of the Gross Glockner in the east. There are large outcrops of it in the Pennine range on both sides of the watershed near the Théodule Pass—as, for instance, near Gressoney, at the head of the Val d'Ayas, on the pass itself, and in the Petit Mont Cervin, all about the Riffelhorn, and in the peaks south of the Mischabelhörner, from which it may be traced by sporadic outcrops to the headwaters of the Tosa. Similar outcrops occur in other parts of the Alps, the most noted being that

[1] *Quart. Jour. Geol. Soc.*, vol. lxi. (1905), p. 690; vol. lxiv. (1908), p. 152.

on the north side of the Brenner Pass, where, at Sprechenstein, the mineral variety antigorite was first clearly described.[1] So far, however, as I know, neither form of serpentine has been found in the Oberland or in the Dolomite Alps. The antigorite-serpentine is a little harder and distinctly tougher than the bastite-serpentine. The one, when exposed to great pressure, assumes a fairly regular cleavage like a slate, as may be seen on the Viso, near the Col de Vallante, and by the little tarn at the base of the Riffelhorn, where I have picked up flakes hardly thicker than visiting-cards;[2] the other is more brittle, cracking and ultimately forming rather shuttle-shaped pieces, with glazed exterior (slickensides), but with little alteration, beyond crushing, of the inner structure of the rock. It is associated sometimes with the calc-mica schist, but more frequently with the green schist, and when the junctions are clear (they are often obscure) is certainly intrusive. Sometimes it cuts the gneiss, but this is not often seen, though it must pass through that rock to reach the other two. The variety antigorite, which has more resemblance to a mica (though without its metallic lustre) than to ordinary serpentine, has been asserted to have been formed from augite, but this is not the case, though that mineral is apparently rather readily converted into it.[3] These serpentines are the latest of the crystalline foundation-stones of the Alpine region, among which we include them on negative

[1] See references in *Quart. Jour. Geol. Soc.*, vol. lxi. (1905), p. 690.

[2] *Geol. Mag.*, 1890, p. 536.

[3] *Quart. Jour. Geol. Soc.*, vol. lxi. (1905), p. 690; lxiv. (1908), p. 152.

rather than on positive evidence.[1] In the Apennines they are in several places intrusive in strata of the earlier Tertiary age, while olivine rock occurs in the Ultenthal (Tyrol) and at the southern base of the Graians in so fresh a condition that it is difficult to understand how it can have been preserved unchanged from so remote a period. Still, as there are granites and rocks allied to basalts in the Alps, which differ greatly in antiquity, it is also possible there have been two outbreaks of olivine rock.

We are now confronted with an important problem, namely, whether any of the gneisses or schists are metamorphosed representatives of rocks of Palæozoic or later ages. But this, perhaps, can be more easily dealt with, if we first give a brief sketch of the physical conditions in the Alpine region during those ages. At the present time, few, if any, geologists would demur to the assertion that in this region the bulk of the crystalline rocks are much older than any sedimentaries to which a date can be assigned, and may be classed as Archæan, because of their close resemblance to the gneisses and schists which can be proved elsewhere to belong to that era. But the geological history of the Alps until the Carboniferous period is almost a blank.

Putting aside for the moment a rather considerable group of schistose rocks, the *glanzschiefer* or *schistes lustreés* of many geologists, we can say that the Silurian system, including therewith the Ordovician of many authors, is the oldest member of the Palæozoic series which has been identified in the Alps, and this only

[1] Prof. J. W. Gregory obtained proof that a serpentine near the Mont Genèvre Pass was Pre-Triassic (*Quart. Jour. Geol. Soc.*, vol. l. (1894), p. 303).

on the northern range eastward from the mouth of the Zillerthal. It consists of grits, such as the older geologists often termed greywacke, and slaty argillaceous rocks, with rather glazed surfaces (phyllites), the age of which is fixed by the occasional presence of fossils, sufficiently well preserved to admit of identification. These show that a sea, probably rather shallow, overspread a considerable part at least of the Carnic and Karawanken Alps. They are sometimes succeeded on the northern side by rocks of a generally similar character and by occasional limestones belonging to the Devonian system, which also are rather well developed in the extreme east to the north of Graz in Styria. Rocks of Carboniferous age, though with sundry interruptions, are found over a wider area. On the northern side of the Eastern Alps beds occur with plant remains and other fossils, which indicate conditions more or less marine; on the southern, as in the Gailthal and at other localities, the alternation of beds containing marine fossils and those with plants shows oscillations between sea and land. Farther west in the Tyrol, and in most parts of the Central Alps, rocks of Carboniferous age cannot be identified. But they are probably present in the trough of the Upper Rhone valley, more especially on the southern side, westward from the neighbourhood of Brieg, and perhaps even from the Binnenthal; the identification becoming more certain as they are followed in that direction. Below Sion the Carboniferous rocks begin to be divided; one belt passing through the mountains to the south of Saxon, where a little anthracite occurs, and running as a narrow strip south of the Mont Blanc range, near the Col of the Little St. Bernard. Beyond this it begins to broaden out in the Tarentaise and the Maurienne, whence it can be traced, gradually narrowing, to the neighbourhood of Briançon. The northern strip crosses the Rhone valley near Vernayaz, runs by Salvan and Finhaut to near Argentière, and reappears (on the northern side of the range culminating in the Aiguilles Rouges) in considerable force in the mountains near Servoz. From this district it may be traced south-westwards, but with many interruptions, as far as the Romanche, where it is last seen in two narrow infolds in the Combe de Malaval. Except perhaps in the beautiful subcrystalline limestone at Saillon, to which we shall return, it gives no sign of a marine deposit.

The Carboniferous rocks over all this area are breccias or conglomerates, and grits or slates, more or less carbonaceous, and the organic remains, if any, are those of plants. They yield, however, valuable evidence in regard to the early history of the district now occupied by the Alps. Some of the most significant sections may be examined on the ascent from Vernayaz by Salvan to Finhaut. An important bed of breccia or conglomerate, underlying finer sediments (now converted into a black slate) is doubled up sharply between the fairly coarse gneisses severed by the Gorge de Trient; being crossed and recrossed by the carriage road, which is the successor of the old mule-track.[1] The fragments in the breccia, angular or subangular, but seldom at all well rounded, are embedded in a variable quartzose grit, in which fragments of mica are sometimes rather thickly scattered. They consist of the following materials:

[1] During the last few years a railway has been constructed.

(1) vein-quartz (white), perhaps the most abundant, the fragments ranging about 4 inches in diameter down to the smallest size; (2) a gneiss, consisting chiefly of felspar and mica with but little quartz; (3) another gneiss with a brownish mica; (4) a fine-grained, rather granitoid gneiss with a moderate or slight amount of white mica; (5) a very filmy mica-schist, in which a silvery mica is abundant; (6) a dark mudstone. (2) is often more or less contorted, and represents some rock outcropping in the neighbourhood; (3) and (4) are very like varieties of gneiss seen *in situ* above the Gorge of the Trient; while (5) resembles a variety of the calc-mica schist, which occurs on the Great St. Bernard and elsewhere. It is often evident that a rock had become foliated and in some cases a schistose cleavage had been produced before the fragment was detached. Similar evidence may be found in other places; and as strong streams would be needed to transport material of this kind, we are justified in inferring that in the Carboniferous period highland, if not mountainous, districts, composed of rocks similar to the foundation-stones of the present Alpine chain, must already have existed on its site. This is not all; the Secondary limestones which pass across the Rhone from the Western Oberland towards the Dent du Midi and the mountains of Savoy were evidently laid down upon the truncated edges of this Carboniferous infold. Similar, but even stronger, evidence may be found in the valley of the Romanche. Here, on either side of Freney, the well-known ravine of the Combe de Malaval has cut through two infolds of Carboniferous rocks. Fragments in one of them prove that the parent rocks had been foliated and sub-

jected to earth movements in Pre-Carboniferous times. These infolds, both far from thick—the lower one is only a few dozen yards across—are almost in a vertical position, and the well-stratified Secondary (Trias) rocks above pass from one surface of gneiss to another right across the truncated edges of these folds. Thus this long-forgotten Alpine region must have undergone great folding and great denudation in later Palæozoic times. The date of these movements cannot be very precisely fixed, but it probably belongs in the main to a long interval, which has left but little record, between the later Carboniferous and the earlier Permian deposits. In not a few parts of the Alps a rock occurs called Verrucano, which is stratigraphically more closely related to the Trias than to the Carboniferous, for, like the former, it sometimes passes across infolded masses of the latter.[1] It often consists of a breccia or conglomerate, mainly composed of the older crystalline rocks and having a more or less schistose aspect as an indirect result of subsequent pressure, which is occasionally overlain by a certain amount of limestone or dolomite. This description applies to the representatives of the Permian system, which occur in the Western, Central, and parts of the Tyrolese Alps; but in the regions around Botzen are great masses of effusive igneous rocks, which belong to the earlier part of the period. These are followed by a red sandstone—the Grödner Sandstone—and that by a limestone containing fossils; both of which occur in the eastern part of the Southern Alps and in the Karawanken Alps; while in the latter some marine limestones represent the earlier part of

[1] See E. Fraas, "Scenerie der Alpen" (1892), p. 93.

this system.[1] Molten material—probably as a consequence of those movements—was forced up from below in several parts of the Alps, but in most of these the outcrops now visible are both isolated and limited in extent like the "porphyrites" of the Windgälle in the Maderanerthal or that in the mountains on both sides of the Rhone below Martigny. But vast floods of lava (varieties of porphyrite) were poured out over an area which extends, speaking in general terms, from Meran on the north to Trient on the south, and from the Val de Non on the west to near Primiero on the east. These lavas rise high on either side of the beautiful glen of the Kuntersweg, through which the Eisack has carved a path in its way to join the Etsch at Botzen. They are traversed by the two mountain roads from that town to Predazzo, and help to make this a happy hunting-ground for petrologists. It is also possible that some rather outlying granitic masses in the Alpine chain may have been intruded during this period; such as the granites in the Baveno district on the Lago Maggiore, that in the upper part of the Gasterenthal, that of the Cima d'Asti, and the tonalite of the Adamello *massif*. But on this question it is almost impossible to speak with certainty. So far, however, as we are aware, no sediments of Triassic or later age in the Alps are actually cut by a granite.

The representation of the Triassic system in the Alps is variable in amount and in character. Rocks of this period are grandly developed in the Eastern

[1] Other rocks in the Swiss Alps have been referred to this period, but this question will be considered at a later stage.

Alps on each side of the central range; and on the southern one discharges of molten material, both effusive and intrusive, continued from the preceding period. To these belong the basaltic tuffs (sometimes fossiliferous) and agglomerates of the South-eastern Alps, which are intercalated among dolomites or limestones, mostly of lower Triassic age. They extend from the Seisser Alp, to the north-east of Botzen, almost to Cortina in the valley of the Piave, and the interesting crystalline intrusions in the Predazzo district may perhaps represent the expiring efforts of this age of subterranean disturbance. Volcanic rocks are absent from the great masses of Triassic limestones, dolomites and marls on the northern side of the central range, but important beds of salt indicate the conditions of deposit to have been locally exceptional. So they were, not unfrequently, in the Central Alps. There in some places the Trias is altogether absent; in others it is represented by a limestone called rauchwacke, often soft, crumbly, and yellowish in colour, which is not unfrequently associated with beds of gypsum, but locally it becomes more solid and bears more resemblance to the dolomitic rocks of the Eastern Alps. For instance, on the northern side of the Val Bedretto, both east and west of Airolo, the pulverulent rauchwacke is very thin; on the Nufenen Pass, and still farther east in the direction of the Gries Pass, the Liassic rocks either rest directly on ancient crystalline schists or are parted from them by a few feet of rauchwacke. North of the Lepontine axis, in the similar infold along the upper valley of the Reuss and on the Furka Pass, the rauchwacke, if present at all, is very thin. The variability of the representation of the Trias is well demonstrated in its eastward prolongation from Airolo. In the Val Piora district, at the western end of the Lago Ritom, we find only thin strips of rauchwacke, nipped between crystalline schists of much greater antiquity; but, after gaining the step beyond the eastern end of that lake, we see the rauchwacke quickly becoming thicker and including well-marked deposits of gypsum. Yet farther east, at the head of the upland valley, the whole length of which is barely five miles, we find the often friable rauchwacke replaced by a mass of dolomitic limestone, which must be fully 600 feet thick, and is strong enough to form the bold crags of the Pizzo Columbè, which rises to a height of 8,363 feet.

In the Tarentaise and Maurienne the Trias, generally a limestone of some kind, is, for the most part, but feebly represented. Around the crystalline *massif* of the Pelvoux it is often wanting,[1] but it appears farther to the west in Dauphiné, and may be traced from the above-named northern districts to the eastern side of the main watershed and thence southwards into the Maritime Alps. The Triassic deposits accordingly indicate that in the Central and Western portions of the Alpine region a shallow sea was invading during those ages a hilly and rather barren district, and forming lagoons which were often favourable to the precipitation of salt and of gypsum; this sea becoming more open in character towards the south-east, where fossils and even coral-reefs are not seldom abundant. We may admit this to be true

[1] Below the northern cliffs of the Meije and on the Col de la Lauze (11,625 feet) the Liassic slate rests on crystalline rocks.

From a photo by] [*Signor Alessandro Cassarini, Bologna.*

4. VIEW FROM FROPPA GLACIER, MARMAROLA.

To face p. 42.

without going so far as to maintain that some of the curiously insulated dolomitic masses in the district east of Botzen are actual atolls, and still retain, after these myriads of years, not a little of their original form. In the Eastern Alps also the Rhætic system, which in our own part of Europe is so poorly developed, attains a great thickness, and includes an important mass of limestone or dolomite which takes its name from the Dachstein mountain. From this also the Marmolata, Tofana, Drei Zinnen, Pelmo, and other important peaks in the south-east Tyrol have been sculptured.

The deposits of the Jurassic period mark a long and steady subsidence, for they extend over almost the whole of the Alpine region, and occur in a way which leads us to suspect that they were once present even in the places where they cannot now be found. The formation is marine throughout, and not seldom passes into one indicative of distinctly deep water. It presents two types, in the one of which clays, in the other limestones, are dominant. The former, which are sometimes curiously like certain members of the English Lias, occur in the western part of the northern Alpine zone, and consist of grey or black clay streaked with calcareous strata, which are suggestive of deposit at a rather small or at most a very moderate depth; while the latter are mainly composed of limestone, with occasional cherts, which must have been laid down in a fairly deep sea. Conglomerates and breccias are extremely rare, if not altogether absent; and during this geological period the highland region which, at the beginning of the Mesozoic era, occupied no small part of the site of the existing Alps, must have given place to an ocean. The higher (and usually the larger) part of the Jurassic system—the Lower, Middle, and Upper Oolites of our own country—is represented in all the great Alpine districts occupied by sedimentary rocks, though the equivalents of the first and second are generally less well developed than the third. In the Eastern Alps all three are often missing, probably having been removed by denudation; but in proceeding westward we find them becoming more important constituents in the mountain ranges, especially on the northern, and ultimately on the western, side of the crystalline watershed in this part of Europe. On the Italian side both they and the underlying Trias disappear no great distance west of the Lago Maggiore. But on the other one, the limestone precipices, now towering unbroken to a vast height, now forming terraced walls, alternating with green or forest-clad slopes, are carved from rocks representing the Middle and the Upper Oolites of Britain, where clays predominate and the variable beds of limestone never reach a thickness of 50 yards.

Rocks of this age, infolded with those of a later date, but generally similar in character, extend in a broad belt through the Western Oberland, across the valley of the Rhone and the upper end of the Lake of Geneva into Savoy. This belt continues through that province, running west of the crystalline zone which extends from Mont Blanc to the Dauphiné Alps, and is severed successively by the Isère and the Romanche, broadening out in the direction of Provence until it is for the most part buried beneath deposits of later date.

Next in succession comes the Neocomian system, more commonly called the Lower Cretaceous by British geologists, but as both it and the Upper Cretaceous of the latter are well developed in most parts of the Alps, and exhibit marked differences in their fauna, it seems better to regard them as independent. The Neocomian is not very strongly developed in the Eastern Alps, either Northern or Southern, but in the Central and Western Alps it assumes a more important character and includes some thick beds of limestone. These, for instance, form the grand cliffs of the Diablerets, both in the huge cirque of the Creux de Champ and near the scene of the famous bergfall on the Pas de Cheville. Similar limestones, often very compact, cream-coloured, and excellent for structural purposes, are well developed in the Jura, together with those of the preceding system, and continue to be an important feature after that range has merged with the main chain of the Alps; the noted ravine of the Perte du Rhone, some twenty miles below Geneva, being excavated in rock of this age.

The Alpine representatives of the next formation, the Cretaceous (or Upper Cretaceous) differ widely from those in Britain and north-western Europe, for we find among them nothing like the white chalk of the English Downs. Nor do we meet with those hard, compact, cream-coloured limestones, with not unfrequent chert, which represent that chalk in the Mediterranean region. The site of the Alps was still occupied by a sea, but this was becoming shallow, so that its limestones are more or less mixed with sand or mud. These rocks generally afford rugged and barren, but not impressive, scenery, for the rainfall often speedily disappears down natural drainpipes. In the Eastern Alps, however, both north and south of the central axis, limestones of this age become more important; as, for instance, the Untersberg "marble" of the former and the scaglia of the latter. In both of these the genus *Hippurites*, a fossil rare in the British chalk, but abundant enough in Southern France to give its name to a limestone of that age, is more or less common. Neither do we find rocks resembling either the Upper Greensand of England or the blue clay of our Gault, though in the Perte du Rhone district an argillaceous deposit rich in phosphate nodules, and with abundant fossils, is rather like certain deposits in this country which occur in one or other of these formations near their border line.

In some parts of the Alps the Cretaceous system includes an important deposit, which occasionally presents some peculiarities, difficult of explanation. It is called the Flysch, but, since it represents a *facies* or consequence of similar physical conditions, which seem not to have prevailed simultaneously but to have travelled slowly from east to west in the region now occupied by the Alps, it may be better to defer any further description of this group of rocks till we have noticed those indubitably of Eocene age, which also are involved in the Alpine folds. No physical break, such as exists in Britain, separates the Mesozoic from the Kainozoic series; the Cretaceous in many parts passing up into the Eocene. The representatives of the latter (excluding the Flysch) are almost restricted to the northern outer border of the Alps, and include a limestone with *Nummulites.*[1] This member of the Eocene is developed in the Briançonnais, and again, after an interval, in the Savoy Alps, the Dent du Midi, the Diablerets, and from this eastward through Switzerland into the Bavarian and Tyrolese Alps. The nummulitic beds are well developed at Appenzell and near Einsiedeln, and the genus is abundant in the oolitic ironstones of the Kressenberg, near Traunstein in the Bavarian Alps. Deposits of this age are rather extensively developed on the southern slopes of the Eastern Alps; while at Ronca and other places in the Vicento-Veronese district, some basaltic tuffs and lavas indicate eruptive activity at this epoch. Here the chief characteristics of the marine fauna are the relatively large size of its shells, the presence of reef-building corals, and the great abundance of sea-urchins. The calcareous shales of Monte Bolca, with their rich fish-fauna, belong to the same geological period.[2] Not very long after this, perhaps when the fluvio-marine Headon Beds were being deposited in England, the first of the great earth movements was initiated to which the Alps owe their birth.

In the northern zone of the Alps the total thickness of the deposits included under the name Flysch often reaches some hundreds of yards. They vary in most places from clays to sands; the former being generally rendered more or less slaty by pressure, but they occasionally include beds of conglomerates or breccias, the character of which, as will presently be

[1] A peculiar chambered foraminifer, which presents a rough resemblance to a coin and sometimes exceeds an inch in diameter.

[2] Kayser and Lake, "Text Book of Comparative Geology" (1893), p. 337.

noticed, is often remarkable. On the extreme east the Flysch is more or less sandy, and thus bears the name of the Vienna Sandstone. In the neighbourhood of this city some of the lower beds actually contain fossils of Neocomian age, so that hereabouts Flysch conditions are supposed to have been initiated, even before the Cretaceous period, and to have lasted into the Tertiary era; but as we proceed westwards into the Swiss Alps its beginning must be assigned to a later date, until it may be regarded in this district as more or less an equivalent of the lower part of the Tertiary; and at last in the southern part of the Western Alps the Flysch represents little more than the Upper Eocene with some portion of the Lower Oligocene. "Coming events" evidently must have been casting their shadows before them. The zone now occupied by the Alpine chain was beginning to be disturbed; the sea was shallowing; land at no great distance was being attacked by agents of denudation, and the waters, in consequence, were becoming charged with sediments.[1] These, as we have said, vary from muds to sands, but certain rather sporadically distributed beds of breccia are their most peculiar and perplexing features. Those in the Habkerenthal,[2] long ago attracted the attention of geologists. Here the Flysch is "a brownish to blackish, rather gritty fissile mudstone. It contains occasionally thin bands of hard sandstone and lenticular masses of

[1] The Flysch has been recently compared, so far as its dominant finer-grained material is concerned, with such deposits as the uppermost Silurian and the Permo-Carboniferous in Britain (W. W. Watts, *Quart. Jour. Geol. Soc.*, vol. lxvii. (1911), p. lxxxiv.).

[2] North of the Lake of Thun, a few miles from Interlaken.

breccia or conglomerate. The fragments in this are commonly subangular or subrotund; sometimes it becomes a coarse grit, and sometimes contains boulders bigger than a man's head. The material of the matrix (generally indurated) apparently has been derived from granitic rocks; in parts it becomes a fairly uniform quartz-felspar grit, but when the fragments vary much in size a few represent sedimentary rocks. Thin streaks of mudstone sometimes interrupt the lenticular masses toward the outside, and the mudstone itself may contain isolated boulders or fragments. I was unable, in the time at my disposal, to find one of the very large boulders *in situ* in the Flysch, but several lay in the bed of the stream, the biggest of which (rather rounded) measured roughly 4 by 3 by 3 yards."[1] The late Sir R. Murchison mentions one which measured 35 by 30 by 15 yards, or was not less than 400,000 cubic feet in volume.[2] In these blocks at least half a dozen varieties of granite are represented, which do not correspond with any now visible in the Alps, and one, a porphyritic kind, much resembles a granite in the Schwarzwald.

The valley of the Grande Eau above Le Sepey affords still better sections of breccias in the Flysch. "These exhibit a series of bedded limestones (dark), mudstones, grits, and breccias, forming apparently an ascending series, and dipping variably, but as a rule rather steeply, in a south-easterly direction. . . . The following is a summary of the principal facts: the breccia, in which signs of stratification may be detected, is regularly interbedded with limestones, mudstones,

[1] *Quart. Jour. Geol. Soc.*, vol. lviii. (1902), p. 194.
[2] *Id.*, vol. v. (1849), p. 212.

or grits, passing at the top or bottom (generally rather rapidly) into one or other of them, but in the case of the first or second a thin layer of grit may intervene. Beds of breccia are numerous between Le Sepey and the ravine of the Raverettaz, varying in thickness from less than 18 inches to several yards, but apparently becoming thicker and coarser as they ascend. On approaching that ravine we find a thick mass of grit or gritty limestone setting in, which passes locally and rapidly into a breccia," in which the fragments are generally small, but now and then "a boulder 3 or 4 cubic feet in volume may be found in a mass where the bulk of the fragments do not exceed 5 inches in diameter and are mostly much smaller. On the left bank of the Raverettaz stream we speedily come to the great mass of breccia," which according to Professor Renevier and Dr. Schardt,[1] may be traced for about 2 kilometers to the north-west and 5 kilometers to the south-east (where the beds are lost beneath overthrust Jurassic strata). In this mass the volume of the matrix, a dark gritty mudstone, is less than that of the fragments, which vary greatly in size, the majority being less than 5 inches in diameter, and the remainder measuring anything from that up to several cubic feet, the largest being granite or gneiss. The above-named authors enumerate eight varieties of the former and three of the latter, with sundry crystalline schists. There are, however, a fair number of sedimentaries—grey limestone, sometimes in large blocks, dark, slaty rocks, generally in small bits, and quartzites. The microscope reveals the presence of marine organisms in the matrix, and the above-

[1] *Ut supra*, p. 196.

named geologists have occasionally found specimens of larger size, which have led them to place these beds at the top of the Eocene system. The granites or gneisses have a general resemblance to what can be seen in adjacent Alpine regions, though for the nearest exposure of the former at the present day we must go some 11 or 12 miles to the south-south-west, and we may say the same of some of the other rocks. The fact that the materials of this breccia can be identified within no great distance removes one serious difficulty which besets us in the Habkerenthal, but leaves others which are equally perplexing. These more or less stratified breccias of the Le Sepey district must have been formed beneath the sea. They might be some kind of a fringing deposit on a large scale, but unless the crags from which they fell, though within a few yards, are everywhere concealed, a thing which is far from probable, they must have been carried, at any rate for some distance, to their present position. Neither ocean currents nor the rush of torrents from neighbouring highlands would be strong enough, of themselves, to move boulders of some cubic feet in volume any distance from the shore, and all the evidence in our possession indicates that no parent areas of importance could have been exposed at this geological epoch. Material such as this might have been brought down by a glacier; but in order to form a deposit of this nature it must have extended out to sea, like one of those in Alaska; or débris might have been incorporated during the winter into shore-ice, and floated away when this broke up. But these suppositions require us to assume the existence either of very high mountains or of an exceptionally low temperature. Yet no evidence can be found in favour of the one, and the other implies the occurrence of a glacial epoch in the later part of the Eocene, a period throughout which the climate of Western Europe seems to have been much warmer than it is at the present time. The problem must, we fear, remain among those which await a solution.[1]

At the end of the Eocene, or quite early in the Oligocene, the making of the Alps began, but we must reserve the details of this process for a later chapter, since it can be more conveniently discussed after the leading orographic features of the chain have been described. At present it may suffice to say that the sea retreated northwards and southwards from the Alpine area. In the outer zone of this, however, some marine beds are found, as in the Castel Gomberto district of the southern (Vicentine) Alps, at Miesbach in the Bavarian Alps, at the base of the well-known Rigi, and in other places on the northern margin of the Swiss Alps. These are referred to the Middle Oligocene, and some overlying estuarine deposits to the Upper Oligocene. They, however, are generally inconspicuous; not so the representatives of the Miocene period, most of which are freshwater deposits, though a marine bed, with at least 400 species of molluscs, occurs above the middle of the system in the neighbourhood of St. Gall.[2] They form the major part of the Swiss lowland, extending on the one side, though dwindling in

[1] The difficulties are more fully stated and discussed in the paper to which we have already referred, p. 202.

[2] Kayser and Lake, *ut supra*, p. 300.

importance, into Bavaria; on the other along the western border of the French Alps, round which they sweep till they disappear in the department of the Basses-Alpes. On the southern side similar beds occur, though but rarely. In the neighbourhood of the more lofty Alpine ranges they are associated with, or partly replaced by, enormous masses of conglomerate, which not unfrequently seem to be rather closely related to existing rivers and to be mainly composed of débris from the district drained by them.[1] These beds, as is obvious at a glance, have been affected by subsequent disturbances, but they have not been implicated in the great folds which gave birth to the Alps.

The conglomerates of the Swiss region have long borne the name of Nagelfluhe, or "nail-rock." Excellent examples may be seen on the Speer, near the Lake of Wallenstadt, and in a place yet more familiar to travellers—the grand cliffs of the Rigi, with the neighbouring Rossberg.[2] Here, with occasional intercalated beds of sandstone, they attain a great thickness, for this is estimated in places at fully 5,000 feet. The pebbles are generally considerably rounded, the amount depending to some extent on the nature of the rock. In fact, they bear no small resemblance to those of much later date in the gravels which were deposited in the lowlands by the immediate predecessors of the existing rivers, while the ordinary molasse,

[1] Some pebbles of crystalline rock occur on the Rigi, the source of which is not yet known (*Geol. Mag.*, 1883, p. 511).

[2] The railway from Lucerne to the St. Gotthard passes through a wilderness of blocks of nagelfluhe, the relics of the disastrous bergfall from the Rossberg in 1806.

which occupies a wider area, and is often rather the newer, is a grey sandstone, associated with occasional beds of shale, the former of which is largely used as a building-stone in the Swiss towns. The molasse contains the remains of a large fauna and flora, which have led investigators to the conclusion that the district bordering the Alps—practically the whole region between that chain and the Jura—was a lowland occupied by marshes and lakes; and the fossils suggest that the climate, during the Miocene, was much warmer than it now is, declining from about 16° F. higher than the present mean temperature at the beginning to some 12° at the end.[1] The most noted representatives of the Upper Miocene of Switzerland are the fresh-water marly limestones of Oeningen at the end of the Lake of Constance. From these the late Professor Heer obtained "some 50 vertebrates, 826 specimens of insects, some 40 other invertebrates, and 475 species of plants." The last show a curious mixture of types now occupying widely separated parts of the globe, "American being the most frequent among them. European types stand next in number, followed in order of abundance by Asiatic, African, and Australian. Judging from the proportion of species, the total insect fauna may be presumed to have been richer than it now is in any part of Europe. The wood-beetles are specially numerous and large. . . . Among the inhabitants of that land were species of tapir, mastodon, rhinoceros, and deer. The woods were haunted by musk-deer, apes, opossums, three-toed horses, and some of the strange, long-extinct Tertiary ruminants, akin to those of Eocene times.

[1] O. Heer, "Die Urwelt der Schweiz" (1879), p. 506.

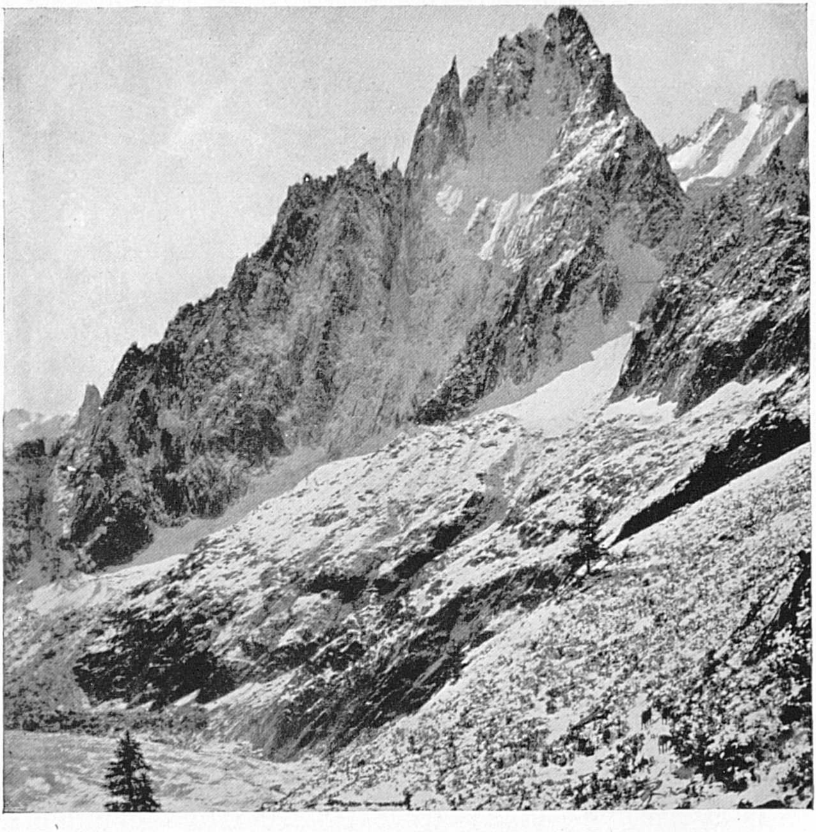
There were also frogs, toads, lizards,[1] snakes, squirrels, hares, beavers, and a number of small carnivores. On the lake, the huge Dinotherium floated, mooring himself perhaps to its banks by the two strong tusks in his under-jaw. The waters were likewise tenanted by numerous fishes, of which thirty-two species have been described (all save one referable to existing genera), crocodiles, and chelonians."[2]

The Miocene period was probably closed, as will be explained in a later chapter, by another important set of earth movements. Since the end of these the removal of material in the mountain regions has been more conspicuous than its deposition, that process having been local, sporadic, and chiefly restricted to the lowlands. No beds of Pliocene age can be identified on the northern side of the Alps, unless it be that the earliest of those indicative of the direct or indirect action of ice really belong to the later part of that period, but it will be more convenient to treat separately these and other glacial and post-glacial deposits. For ordinary marine or even fresh-water strata corresponding with the Crags of England and of Belgium we must look outside the Alpine chain. The sea appears to have retreated from Germany, though it still lingered in the neighbourhood of Vienna, occupied the lower valley of the Rhone as far as Lyons, fringed the Maritime Alps and both sides of the Apennines, leaving its deposits, often of considerable thickness, on the lowlands of Italy.

[1] Among the reptiles was a kind of salamander very nearly related to the large *Cryptobranchus* now living in Japan, which was described in 1726 by Scheuchzer as *Homo diluvii testis*.

[2] A. Geikie, "Text-book of Geology," p. 1270 (ed. 4, 1903).

We must now consider a difficult question, the discussion of which was postponed in the earlier part of this chapter, namely, whether we were right in regarding the great masses of crystalline schists, with which some marbles are associated, as distinctly more ancient than any comparatively unaltered sedimentary rocks to which a date can be assigned. It was formerly supposed that these schists might be representatives of strata of almost any geological age; often Palæozoic, sometimes Mesozoic; the only limit being that as the process of metamorphism had to be carried on at a considerable distance beneath the surface of the earth, it was not very likely that Tertiary strata, thus affected, would have been exposed by denudation. The earlier geologists, however, held that these rocks were the records of a very remote period and of altogether exceptional circumstances in the earth's history. This view fell into disfavour as the Uniformitarian hypothesis, of which the late Sir Charles Lyell was the leading exponent, gradually gained ground, and examples were quoted from the Alps alone of crystalline schists of Silurian, Carboniferous, Triassic, and Jurassic ages. But after that the application of the microscope to petrological research had made our knowledge so much more accurate, doubts began to be expressed whether the Uniformitarian doctrine, though generally a true one, had not been sometimes pushed too far, and whether the processes necessary for producing these changes in sediments, though they may never have ceased to act somewhere in the earth's crust, could have been carried on, during the above-named eras, near enough to its surface to



From a photo by] [*Dr. Tempest Anderson.*

5. NORTHERN SIDE OF AIGUILLES DES CHARMOZ.

To face p. 56.

admit of the results being now exposed. At the present time many, probably the majority of geologists, still maintain the Lyellian opinion, which is not surprising, because it is that generally taught by text-books; and followers of this science are too apt to forget Lyell's own maxim, that in the education of a geologist travel was the first, second, and third requisite, and to prefer long hours in a library, with an occasional personally-conducted rush over sections, to the prolonged and often expensive process of work in the field, with constant testing of its results under the microscope.

In many cases the evidence, supplied by the Alps, in favour of one or the other of the rival views is more or less inconclusive; but the four to which, for want of more space, we must restrict any notice in detail, have been at different times supposed to be decisive for the occurrence of crystalline schists of Palæozoic or Mesozoic age.

1. The magnificent crags forming the northern face of the Oberland range between the glens of the Black and White Lütschine exhibit masses of gneiss alternating with limestones containing Jurassic fossils. These sections were supposed to demonstrate that all the beds belonged to the same geological period, and that some kind of selective metamorphism had converted one set of sediments into gneiss while it had left the other comparatively untouched. It is not, however, necessary to linger over this instance, for it is now generally admitted that the apparent sequence is due to intense folding, coupled with that overthrust faulting, which will be more fully noticed in a later chapter. In fact, these sections did not fully satisfy

even Sir Charles Lyell, for so long ago as 1865 he made the following cautious statement: "I was unable to convince myself that the distinct alternations of highly crystalline with unaltered strata . . . might not . . . be explained by supposing great solid wedges of intrusive gneiss to have been forced in laterally between strata to which I found them to be in many sections unconformable. The superposition also of the gneiss to the oolite may, in some cases, be due to a reversal of the original position of the beds in a region where the convulsions have been on so stupendous a scale."[1]

2. Some of the strata in the remarkable infold of sedimentary rocks of Carboniferous age between typical Alpine gneisses which is exposed on the left bank of the Rhone Valley in the neighbourhood of Vernayaz were supposed to exhibit a considerable development of secondary mica.[2] I have already shown that the breccias in this interesting group contain, in addition to a mass of fragments from the ordinary crystalline rocks of that region, a fair number representing quite ordinary sediments, and that the scales of mica so common in the matrix have themselves been derived from crystalline rocks and were not formed after it had been deposited.[3] But as this case also has been tacitly dropped, we need not dwell further upon it.

At one place a limestone of Carboniferous age might readily be supposed to have been converted

[1] Lyell, "Elements of Geology," 6th edition, p. 752.

[2] In a crystalline rock, like granite, white mica may be developed from the felspar as a result of crushing (see p. 16), but this (so far as I know) is always minute.

[3] *Geol. Mag.*, 1883, p. 507.

into a true marble, such as one of those associated with the crystalline schists. This is on the right bank of the Rhone Valley, near the village of Saillon, about half a league from Saxon. The rock is quarried a few hundred feet above the bed of the valley, and can thus be readily studied. Compact in texture, and varying in colour from a pure white to a darkish green, it is well banded and sometimes "crumpled," so that parts of it, at first sight, present a very close resemblance to, and are hardly less beautiful than, the well-known cipollino from Eubœa. But more careful study, even in the field and still more with the microscope, shows this resemblance to be illusory. The white part of the marble is much less coarse in grain than that associated with the crystalline schists, and is very similar to the purer limestones of the Jurassic or the dolomites of the Trias. The colour-bands are not due to the presence of crystalline silicates, as in the cipollino, but only to some amorphous material too minute for identification even under the microscope. The latter rock, in fact, is one in which all the constituents have been completely recrystallised, while in that from Saillon this process has only affected the calcite—a difference which, we need hardly add, is of the highest importance.

3. Stems of fossil plants, possibly calamites, were asserted to occur in a gneiss near Guttannen in the Haslithal. The specimen was assigned a place of honour in the Geological Museum at Berne; a full description and illustrations of it were given in the official publication of the Swiss Geological Survey,[1] and it was quoted, as if conclusive evidence, in the

[1] *Beiträge zur geol. Karte der Schweiz*, *Lief.* xxiv (1888), pt. iv. p. 161.

Journal of the London Geological Society in 1890.[1] After twice examining the specimen in the Berne Museum, I came to the conclusion that the experts who had identified the objects as plants were probably right, but that the matrix had more resemblance to an arkose[2] than to a true gneiss. A visit to Guttannen in 1891 confirmed my suspicions, for this gneiss was sufficiently different in aspect from the normal gneiss of that and other districts in the Alps to make the erratics from each, as a rule, readily distinguishable, and the former was occasionally associated with beds with a still closer likeness to somewhat altered sediments. I made a second examination in 1895, and two years later visited the outcrop of the "Guttannen gneiss" at the foot of the Gauli glacier, each time with a fellow-geologist. Neither expedition furnished conclusive proof as to the real nature of the rock, and on our return we again examined the specimen in the Museum, from the ends of which pieces had been recently cut. The result is expressed in the following words, written at the time: "If plants, they are very rough and ill-preserved; but if the result of mechanical movements, they are of a most extraordinary and exceptional nature, and the rock certainly has the look of an 'arkose' rather than of a true gneiss." But in 1898 Messrs. E. von Fellenberg and C. Schmidt published an elaborate memoir on the supposed plant-stems,[3] in which they abandoned this view of their

[1] *Quart. Jour. Geol. Soc.*, vol. xlvi. (1890), p. 237.

[2] An arkose is a grit composed of minerals derived from granite.

[3] Separat-Abdruck aus den Mitt. der Naturfors. Gesell. in Bern. Jahrgang 1898.

origin, and relegated them to the motley company of *lusus naturæ*, but demonstrated (though leaving unnoticed some minor points of interest) that the rock was a true gneiss. Thus closed a "comedy of errors," in which none of those who have taken a hand in the game can claim to "score honours"; but in any case the plant-bearing Carboniferous gneiss of Guttannen has gone to the limbo appointed for exploded hypotheses.

4. The occurrence of schists of Jurassic age in districts other than the Northern Oberland was again asserted after the error about these had been generally admitted. The value of the evidence will be sufficiently demonstrated by considering three of the most notable instances. Sections in the upper valley of the Reuss afford the first, the most notable occurring between the southern opening of the Urnerloch and the village of Andermatt, and its members are traversed by the St. Gotthard tunnel. The most important part of this section (Fig. 1),[1] which presents a very perplexing succession of rocks, is at the northern end. Here a fairly coarse gneiss, through a glen in which the Reuss escapes from the Urserenthal, is succeeded by a dark phyllite.[2] Next to this, without any signs of transition, is a crystalline marble, occasionally micaceous; that is followed by a dark limestone of very ordinary type; and then comes a gneissoid rock, different from the first one, and probably a crushed granite. Another jumble, as one may irreverently call it, succeeds this before we reach the crystalline schists and gneisses of

[1] *Quart. Jour. Geol. Soc.*, vol. xlvi. (1890) p. 191, and vol. l. (1894) p. 287.

[2] A slate rather more than usually affected by pressure.

the Lepontine range. The tunnel exhibited a generally similar succession, and the same close apposition of a crystalline calc-mica schist or marble and an ordinary limestone can be seen in other parts of the Reuss valley above Andermatt and on the Furka Pass itself. Two interpretations of these sections are possible, and each presents grave difficulties. If we maintain that the Altkirche marble and the calc-mica schist are members of the Archæan series, we must assume folding and thrust-faulting so peculiar as to be difficult to explain; while if we regard them, like the neigh-

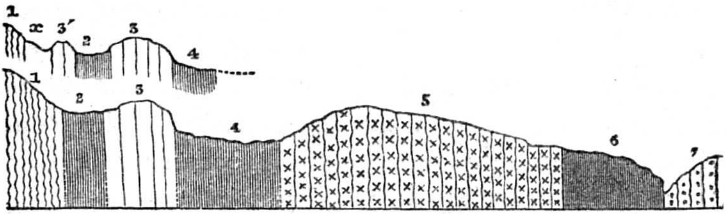


FIG. 1.—SECTION AT ALTKIRCHE.

Length rather less than half a mile. The upper figure represents outcrops higher up the hill.

1 = Micaceous gneiss.
2 = Phyllite.
3 = Marble.
3′ = Second mass of marble.
4 = Limestone, &c.
5 = Sericite gneiss.
6 = Phyllite (Carboniferous).
7 = Hospenthal schists.
x = Covered ground.

bouring dark limestones, as belonging to the Jurassic system, we must postulate an amount of selective metamorphism of which, so far as I know, no other example can be found. One thing, however, is certain, that the chemical changes in the micaceous marble were completed before that rock was exposed to the pressure which has affected the ordinary sediments. Both sides, therefore, may claim a verdict of "not proven," but I am not afraid to maintain that the former view is much the more probable.

The second instance is on the south side of the St. Gotthard Pass, in the Val Canaria, which enters the Val Bedretto just below Airolo.[1] The most remarkable of the sections may be seen on its right bank, in the bed of a small glen ; and it was mapped and drawn in section by K. von Fritsch in his preliminary surveys for the St. Gotthard tunnel. Here a singular succession of rocks is apparently infolded between a mass

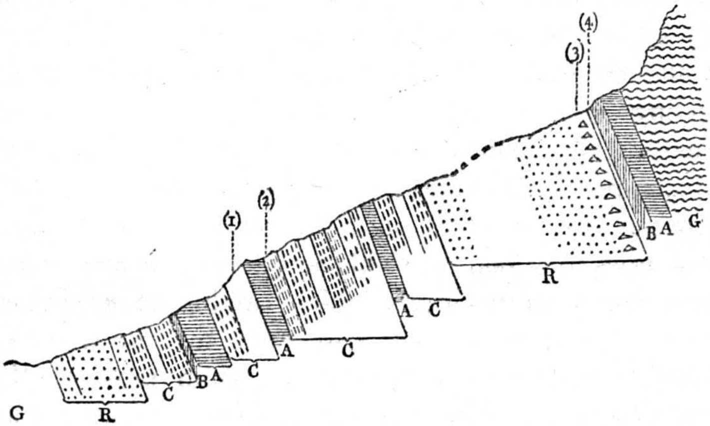


FIG. 2.—SECTION IN VAL CANARIA.

A Dark garnet schist.
B Two-mica schist. (2) Thin band of same.
C Calc-mica schist. (1) Marble forming a small cascade (marble left white).
R Rauchwacke. (3) Breccia of schist fragments. (4) Thin zone of variable schists.
G Gneiss.

of garnet-actinolite gneiss, like that outcropping on the southern slopes of the St. Gotthard road, near the Val Tremola, and the more normal gneiss exposed in the bed of the Val Bedretto, just below Airolo. In descending from the upper to the lower of these gneisses, we pass first over a bed of soft, rather

[1] *Quart. Jour. Geol. Soc.*, vol. xlvi. 1890) pp. 190–217, vol. l. (1894) pp. 297–301.

crumbly yellowish limestone, known in the Alps by the name of "rauchwacke," the Triassic age of which is universally admitted. This is followed by a group of the following crystalline schists : dark mica-schists, with garnets of similar colour ; a silvery very micaceous schist (Grubenmann's two-mica schist) : and calc-mica schists, passing locally into a marble—all of which have been conspicuously affected by pressure—and then comes a thick mass of rauchwacke, containing some gypsum and dolomite, from which we pass to the other gneiss. At first sight we appear to be dealing with an ordinary fold, and if so, since the rauchwacke undoubtedly belongs to the Trias, the schists must be metamorphosed members of the Jurassic system. But we find on closer examination that not only does the bed of "black garnet" schist occur three times in positions which cannot be explained by a simple fold, but also that the rauchwacke contains fragments in abundance from most of the varieties of the schists which, on the supposition that they overlie it, must be later in date.[1] Obviously, then, the rauchwacke is a much more recent rock than these crystalline schists, and their apparent superposition and the folding can only be a rather remarkable result of overthrust faulting, as shown in the diagrams (Figs. 2 and 3), the former of which represents the actual succession of the rocks exposed in the bed of the ravine, the latter the probable interpretation of the section.

[1] The difficulties arising from other sections in this district are described in my papers already mentioned. The only rock I have not succeeded in finding among the fragments is the black garnet variety.

The third instance may be most fairly stated in the words of one of its advocates: "Crystalline schistose rocks of Mesozoic age exist at Scopi, in the Urserenthal, on Piora, at the Nufenen Pass, in the Val Canaria, in the Ganterthal, and numerous other places; such rocks are, (*a*) Clay-slates with mica, garnets, zoisite, staurolite, rutile, and belemnites, the latter being crystalline and granular. (*b*) Clay-slates, with mica, staurolite and garnet, alternating

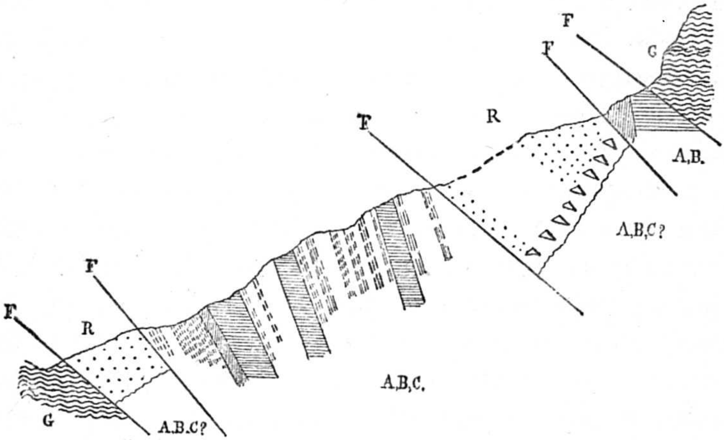


FIG. 3.—INTERPRETATION OF SECTION IN VAL CANARIA.
Lettering as on Fig. 2. F = Faults.

with the belemnite schists. . . . (*a*) Micaceous phyllites and calcareous mica-schists. (*e*) Marble with mica, which has undergone linear stretching, going over into Malm-kalk with crinoids." [1]

The cases already mentioned make it clear that these very positive statements require a careful scru-

[1] Statement printed in *Quart. Jour. Geol. Soc.*, vol. xlvi. (1890), p. 236. See also *Geol. Congress Compte. Rendu de la* 4^{me} *Session*, p. 80, and *Nature*, September 27 and October 4, 1888.

tiny, and that they may have no better foundation than a lax use of the term schist, which has led to a confounding of two very distinct rock groups,[1] and the assumption that an apparent sequence can only be explained as a chronological succession. But, as I have already shown, the most important of them are actually erroneous. Considerable masses of an impure calcareous Jurassic rock, containing belemnites and fragments of crinoids, are infolded with crystalline schists, such as those mentioned above, and with certain gneisses, in more than one region of the Lepontine Alps. One strip runs along the left bank of the Urserenthal, as already stated, and crosses the Furka Pass. Another forms a large part of the mountain called Scopi (10,500 feet), which rises on the east side of the Lukmanier Pass, and is also exposed to the west of it in the Alp Vitgira. It is underlain by rauchwacke, and as patches of this rock, very variable both in quantity and character, occur at intervals all the way westwards to beyond Airolo, a broken fold of Mesozoic strata probably once extended down the Val Piora to the Val Bedretto. Nearer to the head of the latter the dark fossiliferous Liassic rock appears above All'acqua, and can be well studied in outcrops and abundant erratics on the way to the Nufenen Pass (8,005 feet). Here it swerves slightly to the south, runs along the upper part of the Nufenenstock (9,400 feet), and appears on the higher slopes leading to the Gries Pass from the Eginenthal, west of which I have not followed it. The group of true schists, already stated to occur in the

[1] They are laid down quite correctly in Karl von Fritsch's map of the St. Gotthard, published in 1873.

Val Canaria, is generally to be found in the immediate neighbourhood of these Jurassic rocks and the underlying rauchwacke, but it extends over a much larger area. Its members are thoroughly crystalline; they contain well-developed mica, both white and black, garnets, also generally dark in colour, and occasionally rather large and well-developed staurolites. Fragments of some of these schists occur in the rauchwacke, showing that in Triassic ages they had already attained to their present condition. The calcareous constituent of the Liassic rock and of the enclosed fossils has become more or less crystalline, but that change proves very little, the flakes of mica in it and in the rauchwacke, when of more than microscopic size, are derivative and so are the rutiles, which may also be seen in the enclosed fragments. No doubt the dark Liassic rock contains in some localities—as for instance near the Lukmanier, Nufenen, and Gries Passes—a number of "home-born" minerals; some more or less spheroidal, others prismatic in shape—the "knoten" and "prismen" of German writers from at least the date of K. von Fritsch—but these are neither garnets nor staurolites, nor minerals with any affinity to them. So ill-developed and so impure are they that though it is easy to say what they are not, it is quite the reverse to determine their precise nature, either with the microscope or by chemical analysis. The results given by Von Fritsch prove the "knoten" to be some hydrous silicate of alumina and lime, which—probably because of the numerous impurities—does not correspond with any mineral known to me, and the "prismen" to have some resemblance to dipyre. The microscope confirms this, and indicates the presence of a third mineral rather like a colourless chloritoid. Though I have examined several slices of these "knot and prism" rocks, I have never seen a trace of a garnet or a staurolite, except in one case, where, in a layer of breccia near the bottom of the Jurassic beds on the Alp Vitgira, a garnet occurred, in an indubitable fragment from the usual dark crystalline schists and other detritus from the same, side by side with a bit of a crinoid. These "knot and prism" beds, though rather exceptional in character, show but little alteration compared with the various members of the crystalline schists, and the occasional veins and laminæ of calcite in the dark mica-schists of the latter have no other resemblance to the crushed belemnites in the former than that both consist of calcite. In many cases, as on the passes already mentioned, the fossiliferous schistose Jurassic rocks are separated from the crystalline schists by rauchwacke. Though not always present, it is sometimes thick and often contains fragments of the schists; but even if the Jurassic and the dark crystalline schists come in immediate sequence—as they do once or twice near the Gries Pass—they can be distinguished without much difficulty, however crushed the latter may be. Thus the crystalline schists, whatever may be their geological age, are far older than the beginning of the Mesozoic era, and the rocks belonging to the latter never contain either garnets or staurolites, except as fragments derived from the former. These minerals have not been "developed (as now) in places that have undergone crushing," nor have "even Liassic slates with fossils been converted into garnetiferous mica-schists," nor has "the boundary between the old crystalline schists and real sediments in the Alps been obliterated by such processes of dynamic metamorphism and the proper character of the rock altered so as to render recognition impossible."[1] Facts, not personal opinions, contradict these statements, which have no better foundation than mistakes in elementary mineralogy.

Some geological maps indicate, in more than one part of the Alps, a group of rocks, uncertain in physical characters and geological age, which are called by French authors *schistes lustrées* and by German *Glanzschiefer* or *Bündnerschiefer*. These are a fertile source of confusion and a camp of refuge to believers in selective metamorphism. The confusion originated in days before rocks had been studied under the microscope so that some outward similarity could mask inherent differences. Thus the term covers rocks which are simply phyllites, or slates in which enough of a very minute mica has been developed to give the surfaces a silky rather than a glimmering aspect. It also covers true crystalline schists, which present some resemblance to the last, because they have suffered so exceptionally from crushing that their constituent minerals have been almost pulverised. Such a rock may be locally difficult to distinguish from a phyllite, but by careful work in the field it can generally be traced into a normal schist. In the one case the effect of pressure has been constructive, in the other destructive. It may sometimes happen, though more rarely than is often supposed,

[1] Quoted from a translation of the Congress Report. *Nature*, September, 1888, p. 524.

that Nature has so blurred the page as to make the record illegible, but this simply makes the particular specimen of no more use to the geologist than a defaced inscription is to the historian.

Notwithstanding the facts which have been mentioned above, maps and memoirs still continue to assert the existence of gneisses and crystalline schists of late Palæozoic or Mesozoic age, such as the "Permian" Rofna gneiss between Splügen and Hinterrhein and the "Triassic and Jurassic" crystalline rocks in the Zermatt region of the Pennines. I can venture to assert, from a personal knowledge of both, that no valid evidence can be found in favour of the identifications. The former has every sign of being a granite, which in its upward course has carried with it some fragments from an older rock; while all the support I can find for the latter view is that the crystalline schists have sometimes "nipped in" a bit of rauchwacke, much as in the cases already described, while they are identical in character with those which in most places are clearly proved to be much older than that rock.

In the Scotch Highlands the Silurian gneisses and schists of the north-west have vanished at the touch of Lapworth's hammer, and the confused horde of the southern Dalradians is now being marshalled into order; this will also happen in the Alps when it has been recognised that knowledge acquired by the microscope, as well as experience in the field, is necessary in order to solve their problems, and that the hypothesis of uniformity ought not to be so stated as to be inconsistent with that of evolution.

CHAPTER III

HOW THE ALPS GREW

THE Alps are not a simple, perhaps not a single, group of mountain ranges, extending from the neighbourhood of Gratz to that of the Mediterranean. If we examine a geological map, such as that of Noë, we shall see that their core (the older crystalline rocks) does not form one great curving mass flanked on either side with later sediments, or even a line of islands similarly connected, but is more like two pistol-shaped masses pointing in the same direction, and so arranged that the barrel of the one touches the handle of the other. The outer zone of sediments is more uniform on the northern than on the southern side, for there it runs in a practically unbroken sweep from the one end to the other The southern zone follows the peculiar flexure in the crystalline cores, and after a time ceases to appear, probably as a result of denudation, on the Italian side of the western segment. But, as we shall presently see, the Alps cannot be completely separated from other mountain ranges; they are connected on the one side with the Apennines, on the other with the Dinaric ranges. The Jura is like an outpost, which still keeps in touch with them at its southern end. But the chain, as a whole, forms part, as indicated in

Suess's classic work, of a great mountain system related in the same way to the Mediterranean, of which the Carpathians, the Pyrenees, the Atlas, and other mountains of minor importance, form a part. On this, however, we must not dwell; at the present moment it will suffice to notice the existence of these complications, because, as we shall see, they help much in revealing to us the growth of the Alps.

The eastern portion of the chain is the simpler in structure. It consists of a central, mainly crystalline, range, forming the watershed, of a northern and a southern parallel range, composed mainly of sedimentary rocks, each of which is flanked by a subordinate zone of foothills, the northern of which attains rather the greater importance. As might be expected from the structure, the streams descending on either side of the water-parting, and those from the inner sides of the two ranges parallel to it, are received by a system of trench-like valleys, from which they escape either eastwards towards the Austrian lowland, or southwards to the Adige, or northwards to the Danube. The latter river also receives the eastward-flowing water through the channels of the Save, the Drave, and the Mur. The rock masses in the eastern division of the Alps are less conspicuously folded than in the western one; thus the parallel drainage tracks are neither initiated by anticlinal fractures nor determined by synclinal troughs. They are bounded, roughly speaking, on the one side by the sloping flank of the anticlinal core, on the other by the basset-edges of the stratified rocks, beneath which that core is plunging. These sedimentaries are of Secondary or earlier

Tertiary age, though here and there we may find small and often insular patches of Palæozoic strata from the Silurian upwards.

It is not easy to fix precisely the western boundary of this division, but perhaps the Brenner Pass, though obviously open to objection, may serve as well as any other; for beyond this the structure gradually becomes, as already indicated, more complicated by reason of a southward twist of the watershed, so that, as we shall presently see, the sources of the Inn lie far to the south of the head-waters of the Eisack and the Etsch, the united streams of which ultimately pass out from the mountains to find their way to the Adriatic over the plain of the Po. This displacement of the watershed, by whatever it may have been caused, produces a marked modification in the structure-plan of the Alps, for the line of parting bends sharply southwards from the Malser Heide, so as to sweep round by the Maloja Pass, after which it resumes for a time its former course, and with this the zone of the southern sedimentaries rapidly attenuates and ultimately vanishes. The northern zone, on the contrary, attains to greater importance, becomes more intensely folded, displays its underlying foundation of crystalline rocks, and in the Bernese Oberland has thrown up parts of it to elevations little less than those attained in the neighbourhood of the principal watershed. The Alps now begin to sweep round more distinctly to the south. The northern range, after an interval of minor altitude, again rises till it forms in Mont Blanc the culminating point of the chain, and at the same time becomes, as will presently be explained, more complicated in structure. Together with this the watershed gradually approaches towards the Piedmontese lowland, till at last, as at the other end, it splits up to feed a group of rivers, which in this case flow southward towards the Mediterranean instead of eastwards to the Danube.

Another fact must be briefly noticed before discussing these structures in more detail. West of the longitude of Venice the map shows the above-mentioned folds to be affected, especially in the more southern parts, by another and less conspicuous series of anticlines, parted by synclines, which strike N.N.E. and S.S.W. The Lago di Garda lies in a conspicuous example of the latter, which may probably be traced over the Brenner Pass. Another one, less well marked, seems to have suggested the course of the Upper Inn. West of this river these folds are for a time less obvious, though they may be traced with some difficulty in the Pennine chain. But from a little west of the meridian of Turin this transverse folding becomes so pronounced that it may be intimately connected with, perhaps be the determining cause of, that southward sweep of the chain which brings it to the Mediterranean coast. We naturally ask whether these two sets of flexures are the results of simultaneous or of separate movements. The general uniformity of the northern margin of the chain seems in favour of the former view; the broken line of the southern one, and the fact that in the more central part of the chain the angle between the axes of the two sets of flexures is a large one, accord better with the latter.

Another fact greatly complicates the problem. The rocks composing the Alps did not consist, prior to the folding, of a series of strata uniformly superposed one on the other, like a series of quilts, but were not seldom very irregular in form. The chain as it now stands incorporates relics of highland, perhaps even mountain, ranges. One such existed in the Carboniferous period, as is proved by the breccias and conglomerates mentioned in a former chapter; and this period was followed by one of intense folding and effusion of molten rock, which though local, was in one district on a large scale. The Trias, with at least the earlier members of the Jurassic system, was deposited upon a land surface so irregular that there must have been a vertical difference of several hundreds of feet between its highest and its lowest points, even in the western region. The present chain also, as we have already said, is obviously the result of two epochs of successive movement, separated by an interval of repose, during which denudation was both incessant and on an extensive scale. But since a mass variable in strength must differ much in its resistance to stresses, the effects of these, perhaps in themselves not uniform, must often have been extremely complicated. It is also obvious that, as has been experimentally illustrated, very different results will be produced in a flexible mass which possesses comparative freedom of lateral movement, and in one which is squeezed up against an unyielding barrier. In the former case, relief will be found in a series of undulations, which die away gradually; in the other, the mass will be doubled up into superposed folds, perhaps with fracture and overthrusting. But the complications thus produced, though often very considerable, should be of minor importance when the Alpine chain is regarded as a whole. And so they are, particularly in the more eastern part. But we must not forget that each of the Alpine ranges is not so much the outcome of a single fold as of a group of folds; so that its section is a puckered rather than a simple curve; and which of these crumples should form the watershed may have been determined by some comparatively trivial circumstance, so that we must be prepared for considerable irregularity in its course, apart from any diverse action in the erosive agents. The Jura, the Apennines (in many parts), and the Dinaric Alps are examples, with fewer complications, of processes which must have been carried to a much greater extent in the principal chain.

When any strip of the earth's crust is first brought by folding above sea-level, the rain, as it descends the slopes on either side of the crest, carves them into furrows. That crest accordingly becomes the watershed, and will maintain this position though, from causes described in a later chapter, it may be shifted somewhat in either direction. When a second fold is formed, parallel with the first, the streams will be checked in their downward course and their united waters will either form a lake or will travel along a channel parallel with the incipient ranges. In both cases the water must at last find an exit, either round the end of the inferior fold, or by cutting an overflow channel through the latter. This channel will be steadily deepened, unless the second range, from some cause or other, rises so rapidly as to become an insuperable barrier to the stream. In such case a complete reversal of the drainage would be possible, the original watershed becoming in its turn an overflow channel for the waters which have begun their course on the nearer side of the crest of the second fold.

This, however, will be a rather rare occurrence; more commonly the outgoing river will be strong enough to deepen the notch which already exists in the rising crest and to keep open a passage for its waters. In a later chapter we shall discuss this in more detail; at present it will suffice to point to the Rhone as an illustration. It carries the united water from the northern face of the Pennines and the southern one of the Oberland, along the great trench between these ranges as far as Martigny. There its course makes an abrupt bend from W.S.W. to N.N.W., and it has sawn a narrow valley completely through the prolongation of the Bernese Oberland. We must therefore suppose—and it is also true of the Reuss and the Rhine—that the Pennine range had its beginning before the Oberland one, although parts of the latter have been locally pushed up to a very considerable elevation. We can obtain a clearer notion of this portion of the Alps, during the interval between the first and second of the great movements, by looking at the more eastern half, which has better preserved its original features. This also was no doubt affected by the second set of movements (the thrust in both cases having come from the south), for the Miocene rocks of its foothills, especially on the northern side, have been moderately uplifted. But those to the west of the Lake of Constance are carried to a greater height, and the huge pebble beds, in which so much of the earlier chain has found its grave and its monument, have been carried to a height above sea-level, in the Rigi, of 5,905 feet, and in the Speer of 6,415 feet. It may seem, at first sight, a little anomalous that the highest peaks of the Oberland do not lie to the direct south of the line joining these summits, but of one more to the west, which extends in that direction to a little beyond the Lake of Thun. But when we remember that the folding in this second half is even more intense than in the other one, we can understand that, in this case, the disturbing forces would be expended here, and thus produce less effect in the outer zone.

Before proceeding farther we may call attention to a fact which may ultimately prove to be significant. Italy has often been said to resemble a boot in outline, but it has been less commonly noticed that by a depression of considerably less than a thousand feet the Lombardo-Venetian plain would be submerged and the Adriatic extended to the feet of the Western Alps. In such case that sea would also be boot-like in outline, and would be surrounded by a crumpled border, the folds of which would become more intense beneath the sole, and most of all from the ball of the foot to the beginning of the toes. Were it not that an elevation of the same amount would convert the Adriatic, with the exception of a basin-like hollow in its southern part, into dry land, we should be tempted to think this a cause rather than a consequence of its environment of mountain folds.

We assume, then, that the present line of the Alpine watershed corresponds generally with that which existed in Miocene times, although the structure of the outer zone in the northern and western part has been profoundly modified by the great movement which became intense towards the close of that period. During it also denudation occurred on a grand scale, but the discussion of this question must be reserved for a later chapter; in the present one we shall restrict ourselves mainly to the movements of the crust. We seem to be justified in supposing that when mountain-making pressures began to operate soon after the commencement of the Oligocene period, a solid mass of crystalline rock lay beneath the region which now forms the Swiss and French lowland, to which the Secondary and early Tertiary rocks (extensions of those now folded into the Alps) formed a comparatively thin covering. This crystalline rock now emerges, and perhaps even then did so to some extent, in the highland regions of Bohemia and Bavaria and in those of the Vosges, from which it may be traced by isolated outcrops, west and south-west of Besançon, to the highlands near Autun and the great *massif* of Central France. The resistance of this solid outer region compelled the softer rocks in the zone more immediately exposed to the pressures to buckle up, and when the zone thus folded had become more solid, during a period of repose, this, on a renewal of the pressure, caused its effect to be concentrated more especially on the outer margin, in which new foldings were developed and the older were rendered more acute, until they were torn across and found relief in the sliding of one part over the other.

It is generally admitted that this folding has taken place, and on a grand scale, along the northern zone of the Alps from the Rhine to the Rhone and even beyond that river, but authorities differ as to the extent to which it has been carried or, in other words, as to whether the present juxtaposition of the strata is due to the formation of groups of folds, so completely bent back and doubled as occasionally to bring their upper parts into contact, even for some miles, or to the rupture of such folds and the sliding of the upper over the lower portion.

The mountains south of the Lake of Wallenstadt offer a remarkable example of this problem. In the upper parts of some of them on both the northern and the southern sides, the strata, which at no great distance are in their due succession, are found to occur in reverse order, so that a peak may be carved out of strata older than those which form its base. This reversal was noticed many years ago by the veteran Swiss geologist, Escher, who explained it by the formation of a vast double and flattened fold, with one cusp pointing northward and the other in the opposite direction. His idea was adopted and elaborated by Professor Heim in his classic work,[1] which is illustrated by a number of transverse sections indicating the thoroughness of his explorations. This "double fold" of Glarus at first met with a favourable reception from geologists, but a more prolonged study showed the difficulty of understanding by what movements in the crust of the earth its more superficial strata could be bent from a horizontal position into a curve like the outside of a door-handle, and a study of the sections published in the author's illustrative atlas showed that while faults were but rarely indicated, important

[1] "Mechanismus der Gebirgsbildung," published in 1878.

masses of rock often thinned out and disappeared more rapidly than was likely to occur in a comparatively limited district. Accordingly, Professor Rothpletz and other geologists maintain that these strata have undergone not only folding, but also thrust-faulting on an even greater scale, and that the northern limb of the supposed double fold is formed by an overthrust mass comparable with that to which Professor Lapworth had called attention in the north-west Highlands of Scotland.

We must be content with stating the two interpretations, and presenting the latter one as a diagram, for a discussion of them would involve long and

FIG. 4.—THRUST PLANE IN MOUNTAINS SOUTH OF LAKE OF WALLENSTADT (ROTHPLETZ).

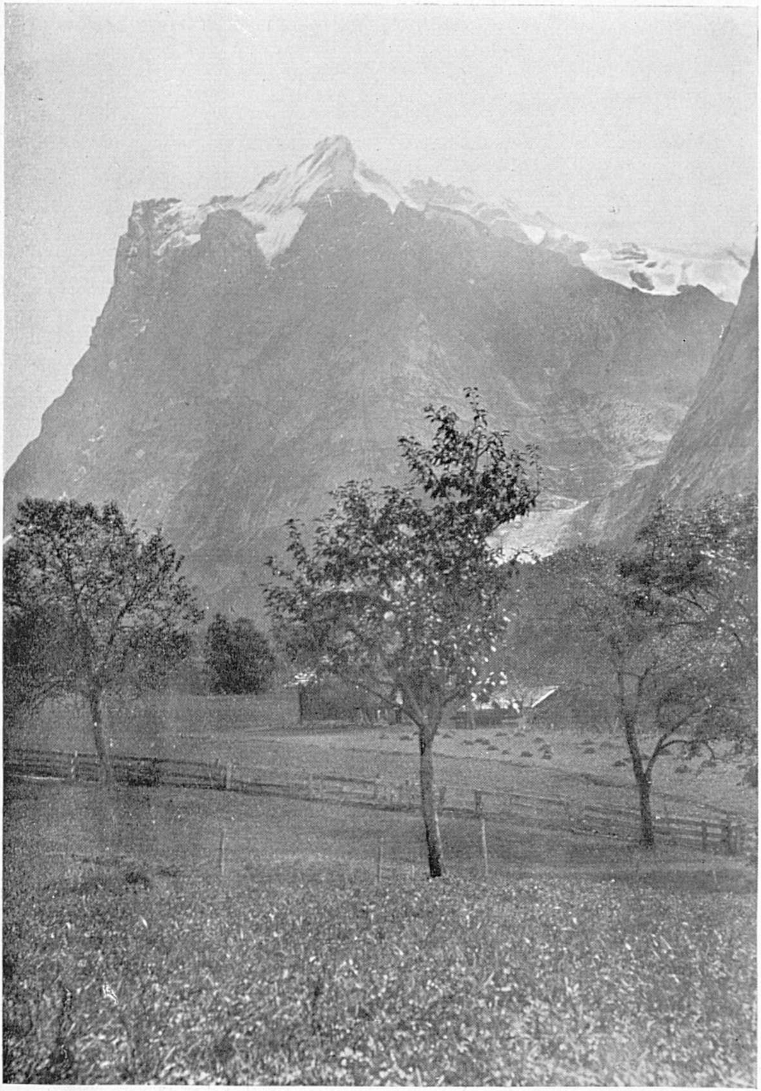
1 = Trias. 2 = Lias. 3 = Cretaceous.
4 = Tertiary. T T = Great thrust plane. 6 = Normal fault.

intricate technicalities; but we may add that, so far as we can form an opinion, the view of Rothpletz seems to involve fewer mechanical difficulties and better to suit the facts than the "double fold," as originally pictured by Heim.

Still farther west the flexures are more abrupt and concentrated into a narrower zone. This is most conspicuous on the northern face of the central *massif* in the Bernese Oberland, west of the valley of the Aar, where a mighty wall of limestone rises for something like a mile in vertical height above the upper pastures on either side of Grindelwald.

The Eiger (13,040 feet) and the northernmost summit of the Wetterhorn (12,150 feet) consist of that rock, which extends westward to form the buttresses of the Mönch and the great precipices of the Jungfrau. But the upper part of both these mountains, with the second and slightly the highest peak of the Wetterhorn, like all the Alpine giants which rise in their rear, consists of crystalline rock. Thus the solid floor of this rock has been bent so as to overtop and even overarch the sedimentaries which once lay level upon it. Nor is this all: in the northern cliffs of the Jungfrau the gneiss appears to be interbedded with the Jurassic limestones, an association which, as stated in a former chapter, for long served as a basis of far-reaching theories of selective metamorphism, but is now recognised as only a case of intensified folding, with a certain amount of thrust-faulting. This district is not the only one in the Alps where a crystalline and a slaty rock occur in juxtaposition. There is one on the northern face of the Meije, above La Grave in Dauphiné, which has long been known to geologists for the sharpness of the contrast (Fig. 5).

This folding of the sedimentary zone continues in the Western Oberland and across the valley of the Rhone into the Savoy Alps, and produces, according to Professor Lugeon and other Continental geologists, a structure in some ways more extraordinary. The Mesozoic rocks in the outer part of this zone (the *Préalpes extérieures* of those authors) often actually "overlie the Miocene conglomerate and sandstone, and frequently exhibit peculiar flat folds (*plis couchés*), which may be compared to a doubled-up *duvet*, together, perhaps, with the counterpane. The strata



From a photo by] [*Rev. T. C. Fitzpatrick.*

6. THE WETTERHORN, FROM NEAR GRINDELWALD.

To face p. 82.

forming these recumbent folds apparently have no underground continuations, and the higher loops commonly extend farther north than the lower. . . . This unusual folding—these extensive, almost flat layers (*nappes*) simulating horizontal stratification—Professor Lugeon explains by supposing that the strata

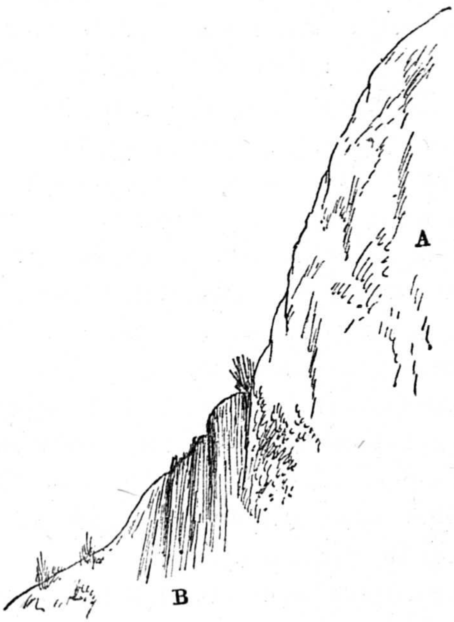


FIG. 5.—SECTION NEAR LA GRAVE.
A. Gneissic granite. B. Dark slate (Jurassic).

thus affected were deposited far away to the south-east; for instance, in the case of the Chablais district, to the south of the present Pennines, perhaps not far from the region now indicated by a broad belt of greenstone extending from Locarno to Ivrea." [1]

Flat folds undoubtedly exist to some extent in

[1] *Quart. Jour. Geol. Soc.*, vol. lxiii. (1907), p. 295.

that district, but this admission does not prove that such extraordinary transgressions have ever occurred. With this matter, which involves many technicalities, I have dealt in a paper from which the above quotation is taken, and endeavoured to show that, though its main idea appears at first sight to be confirmed by Professor Sollas' most interesting experiments with cobbler's wax,[1] these, while illustrating the formation of flat folds, give no real support to Professor Lugeon's principal contention. I have also maintained that some of the sections, which the latter cites as favourable to his hypothesis, are either improbable in themselves, or involve mistakes in the identification of rocks, and that such transferences across the axis of the Alps would be, under the conditions then existing, mechanical impossibilities—impossibilities which do not even require discussion, if I am correct in believing that, with the exception of a slight deviation in the neighbourhood of Mont Blanc, the watershed of the Miocene Alps was substantially identical with that which is still in existence.

We may mention here some rather isolated masses of rock which certainly indicate thrust-faulting, though not movements on such a gigantic scale as those which we have been discussing. These are the *Klippen*, of which the Mythen, the Buochserhorn, the Stanzerhorn, and other similar advance-guards of the Bernese Oberland are examples: "They rise in abrupt pyramids, with steep, sharp points, in striking contrast with the rounded grassy slopes of the Eocene and Cretaceous layers, by which they

[1] *Ut supra*, vol. li. (1895), p. 361, and vol. lxii. (1906), p. 716.

are surrounded and on which they rest." [1] The most probable explanation of these picturesquely anomalous masses is that they are the monumental records of a process of overthrusting, "the last remnants of a range, the intervening parts of which have been removed by denudation." But here also it appears quite unnecessary to assume anything on a scale so gigantic as is demanded by certain enthusiastic advocates of the overthrusting process.

We pass on, then, to the region extending from the left bank of the Rhone, between Martigny and the Lake of Geneva, to the south-west as far as the mountains of Dauphiné, beyond which, as we shall presently see, the chain becomes more simple. The whole of this region exhibits a remarkable uniformity of structure, [2] which may be more easily understood by following it up from the southern end. "Here we find the great crystalline ridges of the Belledonne and the Grandes Rousses, with their infolds of Secondary rock; we find the huge *massif* culminating in the Meije, Ecrins, and Pelvoux, which seems to have been forced like a gigantic plug through the sedimentaries (Fig. 5); bending back their edges and in some cases elevating them in huge arches a mile vertical in height. East of these comes a trough of Carboniferous rocks, which practically can be traced to the valley of the Rhone; and yet farther

[1] See "The Scenery of Switzerland," by Sir J. Lubbock (Lord Avebury), p. 294, for a clear statement of the explanations which have been offered of their structure.

[2] The following paragraphs are extracted from a lecture given at the Royal Institution and printed in the *Alpine Journal*, vol. xiv. p. 116. Though this was written in 1888, my later studies have not led me to change the opinions expressed in the quotations.

east comes the great series of crystalline schists, which can be followed without interruption from the Pennine to the Maritime Alps.

"This last, as a rule, forms the present watershed, and it also indicates, as I believe, that of the Miocene Alps. Low as are the passes of the Genèvre (6,102 feet) and the Echelles de Planpinet (5,783 feet) at the head of the Durance, that river finds its way to the Gulf of Lyons. Hence I consider that the Dauphiné ranges, with their prolongation to the north, owe their present elevations, like the Oberland, to post-Miocene disturbances. This at any rate is certain, that the Romanche, which rises high up in the north part of the main crystalline *massif* of Dauphiné, must from the first have been able to traverse the ridges which prolong the line of the Grandes Rousses and the Belledonne, and which it has now gashed so deeply in the Combes de Malaval and de Gavet. The Dauphiné *massif* also has probably forced the Durance to take at first a southern course. The molasse of the Department of the Isère indicates that there have been great disturbances since it was deposited.

"In the Mont Blanc range we recognise the prolongation of the Pelvoux axis. In that of the Brévent, the double fold of the Belledonne and Grandes Rousses may still be traced. But here an anomaly presents itself. The watershed at the head of the Val d'Aoste deserts the line of the crystalline schists, and, twisting westward around the affluents of the Dora Baltea, passes along the crest of Mont Blanc and its Aiguilles.

"The structure of the region indicated by a geological map would lead us to look for it not far from a line joining the Vèlan with Mont Pourri or the Tsanteleina.[1] . . . If we believe . . . that the Mont Blanc *massif* owes it present supreme eminence to a post-Miocene upthrust, *i.e.*, is contemporaneous with the Oberland *massif*—we are tempted to speculate whether, in this one case, the exceptional elevation attained by that upstart mass may not have interfered with the old watershed and have added to the basin of the Dora Baltea the drainage of the southern flank of the Mont Blanc range and of the trough of Jurassic rock between it and Morgex."

South of the marked gap of the Mont Genèvre, the main chain of the Alps rises again to an elevation, generally exceeding 8,000 feet, occasionally 9,000 feet, and attaining in the grand pyramid of Monte Viso 12,609 feet. "From a point about fifteen miles south of this mountain a number of valleys diverge in many directions, like the spokes of a wheel. These correspond to as many mountain ridges, which all radiate from the Rocher des Trois Evêques (9,390 feet);[2] those to the S.E. and S.W., which extend towards the Mediterranean, being the more considerable. This peak rises near the north-western end of a mass of crystalline rock, which is cut off from the main one of the Cottian Alps by a rather narrow trough of sedimentary strata. To the south of it, the crystallines are no longer visible, and the sedimentaries form the rest of the Alpine region till it reaches the sea. Thus the structures of the two extremes of the chain correspond in more than one respect.

[1] In 1888 these mountains bore another name.

[2] J. Ball, "Alpine Guide: the Western Alps," p. 1. (ed. 1898).

CHAPTER IV

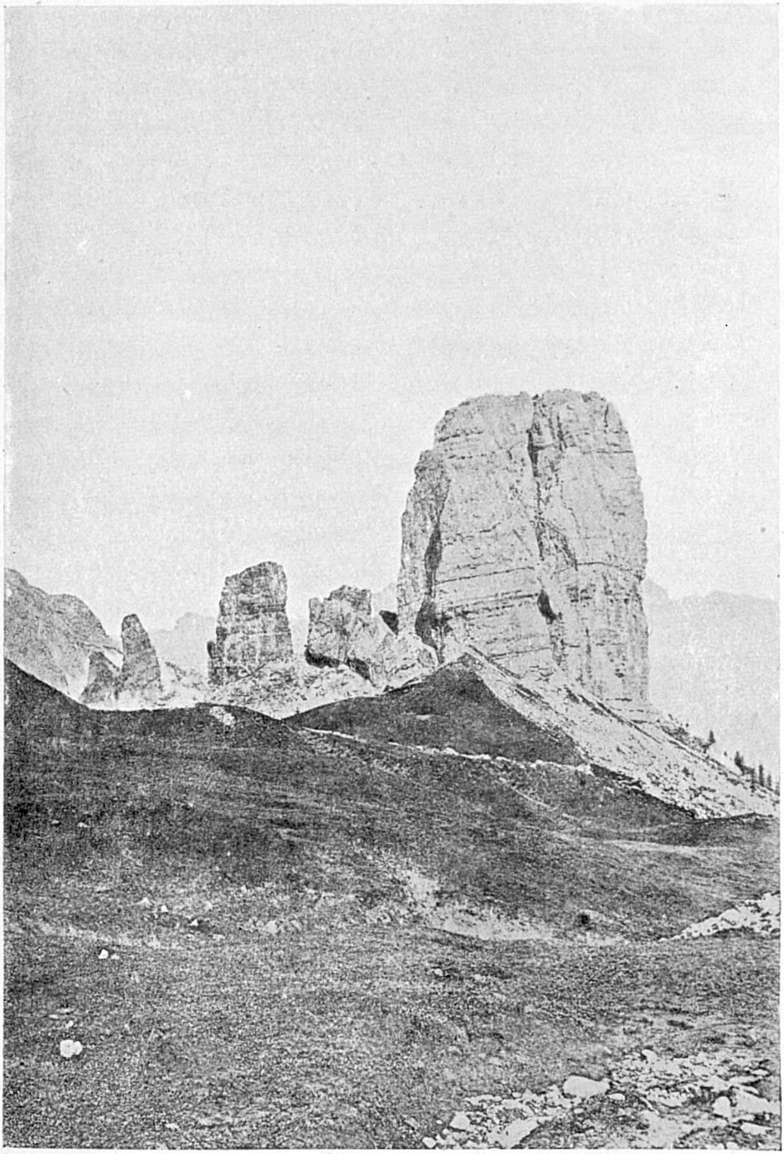
MOUNTAIN FORMS

MORE than half a century has passed since Ruskin published the fourth volume of "Modern Painters," which is devoted to Mountain Beauty and contains some of the keenest observations and most eloquent passages in that classic work. In this interval geology has made great advances, especially in the knowledge of rocks, but the sections dealing with the Materials of Mountains, though here and there containing hypotheses which have had to be discarded, are so full of suggestive remarks that no student of mountain scenery can afford to neglect them. Ruskin groups these materials under four heads, which for all practical purposes are substantially accurate, the classification depending on their condition and structure. First come the Compact Crystallines—rocks which, once in a molten state, have slowly solidified at considerable depths from the surface of the earth, and thus consist of closely interlocked crystalline constituents. These, as a rule, do not exhibit any definite structural arrangement, and the group contains the granites, syenites, diorites, and other fairly coarse-grained igneous rocks. Strictly speaking, it also includes finer-grained rocks of similar origin such as the felstones and greenstones (both not seldom old lava-flows); but as these rarely occupy large areas, we may pass them by as unimportant. The cooling and crystallization of a mass of molten rock makes it shrink, and thus exposes it to strains which produce divisional surfaces, sometimes very uniform in their directions. These are called joints; and any inequality in the rupturing forces may cause one or more sets of them to dominate, but otherwise the mass is broken into large cubical blocks. Their corners, after long exposure to the action of the weather, crumble away, thus giving rise to those hassock-like forms, which may often be seen on the granite tors of Dartmoor.

Next come the Slaty Crystallines. This group contains rocks which, though consisting, like the last, of interlocked mineral constituents that have crystallised *in situ*, exhibit a certain order in their arrangement, and are in consequence more fissile, or in other words "slaty." As already indicated, this structure may be due either to a movement of the mass during the last stage of consolidation, or to the original bedding of materials, which were once fragmental, but have since entered (by the action of heat, water, and pressure) into new chemical combinations, or may be, as is perhaps the most common case in mountain regions, the result of a partial crushing under pressure with some subsequent reconstitution among the smaller fragments. By this process (which in Ruskin's day was very imperfectly understood, though he seems to have had some inkling of it) much of the gneiss in the Alps has been produced and many of their schists have been modified.

The Coherents follow, divided, like the crystallines, into the compact and the slaty; the one including the sandstones, limestones, dolomites and marbles (though the last, as Ruskin points out, are strictly speaking crystalline rocks), and the other the slates and harder shales; for the softer fragmental rocks are obviously not likely to have been employed in mountain-building. In the compact rocks a jointed structure is often more conspicuous than the bedding; in the slaty, fissility often dominates over both. Thus, whether crystallines or coherents, the outlines of the compact rocks often afford a certain similarity, but this, as we shall presently see, is less true of the slaty, because of the superior hardness and durability of the crystallines. The slaty coherents but seldom afford a bold and impressive skyline; while, as Ruskin points out, they produce at elevations unfavourable to plant-life anything but attractive scenery. "There are many spots among the inferior ridges of the Alps, such as the Col de Ferret, the Col d'Anterne, and the associated ranges of the Buet, which, though commanding prospects of great nobleness, are themselves very nearly types of all that is most painful to the human mind. Vast wastes of mountain ground, covered here and there with dull grey grass or moss, but breaking continually into black banks of shattered slate, all glistening and sodden with slow tricklings of clogged, incapable streams; the snow-water oozing through them in a cold sweat, and spreading itself in creeping stains among their dust. . . . I know no other scenes so appalling as these in storm, or so woeful in sunshine."[1]

[1] "Modern Painters," vol. iv. p. 126 (ed. 1856).



7. THE CINQUE TORRE.

To face p. 90.

But, as he goes on to remark: "Where these same rocks exist in more favourable positions, that is to say, on gentler banks and at lower elevations, they form a ground for the most luxuriant vegetation, and the valleys of Savoy owe to them some of their loveliest solitudes—exquisitely rich pastures interspersed with arable and orchard land and shaded by groves of walnut and cherry." Not only so, but it is to the presence of thick beds of shaly or slaty rock among corresponding masses of strong limestone that the northern zone of the Alps from the eastern Tyrol to western Dauphiné owes its exceptional charm.

Of the other three groups, certain districts afford more striking examples than can be found elsewhere in the chain. The compact crystallines, if we use the term in a strict sense, do not generally occur on a large scale in the higher Alps, though Ruskin speaks of the granite of Mont Blanc. In a sense he is quite right, for the "protogine" both of that mountain as well as of its Aiguilles, was originally a granite, but the so-called "gneiss" of the latter is only the "granite" of the former rather more modified by subsequent pressure. Indeed, as we have already stated, it is probable that most of the Alpine gneisses, instead of being metamorphosed sediments, have had a similar origin. Perhaps also, Ruskin, as more familiar with the aspect of Mont Blanc from the neighbourhood of Chamonix, where its upper part presents a comparatively rounded outline, has forgotten that even on this side the Aiguille du Midi is a grand group of splintered crags, while the "calotte" on the west and the south is closely guarded by shattered ridges and attendant aiguilles. Granite bosses, it is true, are not rare on the southern margin of the Alps, but they are small in area and insignificant in elevation; one or two of larger size, such as the Cima d'Asti, occur nearer the heart of the chain, but the most important masses of truly compact crystallines, at any rate which I have seen, are the Mont Collon in the Eringerthal and the Adamello *massif*. Every visitor to Arolla remembers the former, a huge block of a coarsely crystalline rock, called gabbro, in form something like a sponge-cake, its snowy cap of snow or ice rising to a summit, which, though nearly 12,000 feet [1] above sea-level, is far from conspicuous, but is guarded by magnificent crags, which on the more northern face descend almost vertically to the encircling glaciers for some 5,000 feet, with an aspect of strength and grandeur which is not often rivalled. The Adamello, in the southern part of the western Tyrol, is a little lower—its highest point attaining nearly 11,700 feet—but it occupies a much larger area, namely, one about 31 miles in length and not quite half that amount in maximum breadth. It consists of a kind of diorite,[2] called tonalite from the Tonale Pass, which crosses its northern extremity, and is a great tabular mass of rock, draped in the upper part with snow and ice and crowned with two or three rather inconspicuous peaks, but its craggy flanks descend grandly to the deep-cut and rather narrow valleys which run southward from its flanks towards the Lago d'Idro.

[1] The exact height is given as 11,956 feet.

[2] It consists of quartz, plagioclase felspar, hornblende, and biotite.

No better example can be found of the slaty crystallines than the "Aiguilles of Chamonix" and the great horseshoe of ruined fastnesses which form the High Alps of Dauphiné. Among the former, owing to the combined effects of cleavage and jointing, the "pinnacle" shape is dominant throughout the range. It asserts itself in the huge pyramid of the Aiguille Verte and the wedge of the Jorasses; it produces the serrate crests of the Charmoz and Grépon, the Blaitière and Les Plans; it culminates in the immense obelisk of the Dru and the tooth of the Géant, one of the most wonderful among rock forms. We could hardly find, at any rate from a point easily accessible, a more impressive mountain prospect than that of the range of Mont Blanc from the summit of the Brévent (8,285 feet). Across the deep trough of the Chamonix valley, it towers before us from the Aiguille du Tour to the Aiguille du Goûter. Now the grandeur of the Monarch can be fully appreciated. Though it rises above the Arve valley for at least 12,000 feet, the mountain, when looked at from anywhere near, is too much foreshortened, and its upper, the more beautiful part, does not appear in its due proportions. Indeed, we may say with truth of Mont Blanc, that distance lends dignity, if not also enchantment, to the view. Not till we have seen it unclouded from some high peak or pass among the mountains of Switzerland or France can we really appreciate how the Monarch dominates the members of his immediate bodyguard and of their outposts. Never, perhaps, was I so much impressed with its vast bulk as when I saw it one clear, sunny day, more than eighty miles away to the north, from the Col de Cristillian in the Cottian Alps.

It towered into the sky above the rest of the chain in one vast wave of snow and ice, as a solitary breaker will sometimes rise above the ordinary swell of a sea. Hardly less impressive also was the effect, when, late in a summer afternoon, as I was travelling by railway from Dijon to Mâcon, my eye was caught by a mysterious cumulus cloud low down on the horizon, Gradually some darker spots resolved themselves into far-off ridges of rock, seaming the primrose-tinted snows, and I became aware that I was gazing at Mont Blanc from a distance of hardly less than 120 miles. I watched it from time to time as I passed on southwards, till its snows first glowed with the flush of sunset, then turned to a deathlike pallor, and at last the Alpine giant faded like a ghost into the darkening summer night.

Rock-scenery even wilder, though its summits are not quite so conspicuously crowned with pinnacles, characterises the High Alps of Dauphiné which enclose, like a great horseshoe, the head-waters of the Vénéon. This *massif*, though a prolongation, as we have already said, of the Mont Blanc axis, seems at first sight to be almost isolated from the main chain of the Alps, with which it is linked only by the Col du Lautaret (6,808 feet). From the eastern side of this pass the valley of the Guisane descends rather rapidly to Briançon, where it joins the Durance, which, running southward, severs the Dauphiné *massif* from the Cottian Alps. On its western side the Romanche begins its course, passing through the gorges of the Combe de Malaval and Combe de Gavet till it joins the Isère near Grenoble. The great cliffs of the Pelvoux, overhanging the hamlet of Les Claux, are hardly less imposing than those of the Grandes Jorasses: the western and southern precipices of the Ecrins, the monarch of that range, are among the grandest in the Alps, while the steep, broken snowfields, and rugged triangular summit of its northern face are hardly less impressive. The view of its western face from the hamlet of Les Etages in the upper part of the Vénéon valley was depicted by the late Professor J. D. Forbes nearly sixty years ago.[1] It would be difficult to surpass the serrate ridges of the Meije and the Ailefroide or the strangely formed peaks between the latter and the Pelvoux. Boldness, severity, even grimness, are the dominant characteristics of the High Alps of Dauphiné. Their glaciers, however, are generally inferior in size to those of the Chamonix district; while the absence of pine woods and other trees, and the long slopes of broken rock, which are thus exposed in unveiled desolation, give a certain dreariness to the scenery.

The crests of the slaty crystallines are always bold in form and rugged in outline, except where buried deep in snow and ice. To them the phrase "a sea of mountains" is often peculiarly applicable, in which, now and then, a breaker, instantaneously petrified, towers up above the minor waves in solitary grandeur. But even in these cases, as in other matters, much depends on the point of view. Pyramidal forms and sharp summits are often thought to be common, and these characterise such giants as the Weisshorn, the Dent Blanche, and some other mountains less

[1] "Norway and its Glaciers," with appended article on some Alpine Excursions, 1853.

generally known, but the peak is often neither so pointed in its outline nor so complete in its isolation as we might readily imagine. The Viso, when seen from the streets of Turin (by far its best-known aspect) assumes the shape of a pyramid no less graceful than grand. But its true form, as may be seen when it is approached from the west by the valley of the Guil, is a great wedge-like block, crowned by two ruined battlements, of which the one is distinctly higher than the other. The Matterhorn, when regarded from Zermatt, and still more from any of the well-known resorts in the neighbourhood of the Riffelhorn, seems almost comparable in outline to a flaming torch. Yet its summit is an almost level ridge, nearly 120 yards in length; and that spire-like mass which seems to tower fully 4,000 feet above its supporting ridges is really united to the Dent d'Hérens by a curtain wall, which in only one place falls below 11,500 feet.

The forms of the compact coherents are often not less impressive than, though very distinct from, those of the slaty crystallines. In the Alps their materials are calcareous—limestones or dolomites; sandstones occurring only in the outer zones, where they give rise to little more than hilly though remarkably attractive scenery. Occasionally, however, the coarse conglomerates called nagelfluhe, often closely associated with these sandstones, form real mountains, such as the Speer and the Rigi, the former of which more than attains 6,000 feet above sea-level. Their outlines recall those of the compact crystallines, though always suggesting the existence of a stratification in their materials. Most people who have visited Switzerland are familiar with the aspect of the second of these mountains from the lower part of the Lake of Lucerne—a massive block, guarded on three sides by great precipices, but culminating in an undulose area of mountain pastures.

Yet even here the resistance to atmospheric agencies, which makes this striking outline a possibility, is due not so much to the materials, which readily catch the eye, as to the calcareous cement which binds them together. Without that the nagelfluhe would be no more coherent than the pebble beds of the English Bunter. Throughout the Alps the mountains of ordinary limestone take the form of blocks rather than of pyramids, though the Eiger, which towers up so grandly above the valley of Grindelwald, is a striking exception to this rule; and wherever this limestone is interrupted by beds of shale, both being of considerable thickness, the mountains present that terraced outline, that alternation of bare precipice and verdant slope, which is the most marked characteristic and the greatest charm of the limestone regions from one end of the Alps to the other. In those districts where some form of dolomite replaces the ordinary limestones, the mountains often present an extraordinary resemblance to ruined castles; but in many cases, especially where the strata composing them are a little tilted, they assume, as Sir Leslie Stephen once remarked, the form of a writing-desk, which is a common feature in the Western Oberland. Others, however, in the words of the late W. Mathews, my companion in many an Alpine ramble, may be compared, as was the Dent du Midi, to a gigantic molar tooth; but in all cases precipices are the most distinctive feature of the compact coherents. To these we owe that line of giant bastions, parted by glaciers, which extends along the northern face of the Bernese Oberland from the valley of the White Lütschine to that of the Aar—the great buttresses of the Jungfrau, the towering peak of the Eiger, the less aspiring Mettenberg, and the Wetterhorn, with its humbler neighbour, the precipitous Wellhorn. Without forgetting the well-known remark about comparisons, I doubt whether mountain grandeur and mountain beauty are ever more harmoniously combined, at any rate in Switzerland, than when we see, from the neighbourhood of Grindelwald, the vast precipices of the Wetterhorn made ethereal by the shimmering light of a summer morning. Yet one may well hesitate in awarding the prize of beauty, for other districts in the Alps must not be forgotten, such as the limestone Alps of Savoy and those of the Northern Tyrol. In the one the dome-like mass of the Pointe de Tanneverge, though not attaining 10,000 feet, is a most striking object from the neighbourhood of Sixt; in the other, the scenery of the northern district from the Zugspitz eastward, is remarkably attractive; while the Bavarian Königsee and the Austrian lake-land in the neighbourhood of Ischl, have a charm which is all their own.

But the possibilities of the compact coherents are best demonstrated in the Dolomites of the Italian Tyrol, which was almost an unknown land to English travellers till Messrs. Gilbert and Churchill told them of its attractions in their classic volume.[1] The

[1] "The Dolomite Mountains," 1864.

mineral to which they owe their name is a definite combination of carbonates of lime and of magnesia, but the rock to which it has been extended contains a larger, though variable, proportion of the former. This rock, as dolomite is a little harder and more durable than calcite, generally assumes a rather bolder form than the ordinary limestones. Like them, it is associated with other sediments and even with igneous materials, but in this region it chiefly consists of two great masses; the one, which thins rather rapidly eastwards, being called the Schlern Dolomite, and the other, out of which the great crags around the sources of the Piave are carved, the Dachstein Dolomite.[1] This is rather the more distinctly bedded, and thus assumes a yet more definite aspect of ruinous masonry (Fig. 6). The vast precipices of the Schlern and the Langkofl, the cliffs of the Rosengarten and the Marmolata—the chief summit of the range—consist of the former rock; the Primiero and the Ampezzo Dolomites of the latter. These sometimes form a huge pyramid, like the Antelao, or almost rival an obelisk, like the Cimon della Pala; the Croda Rossa, with its red-stained sides, has been appropriately compared

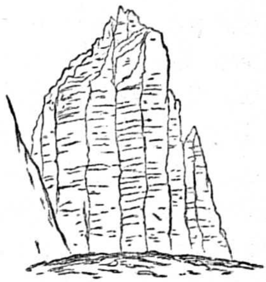


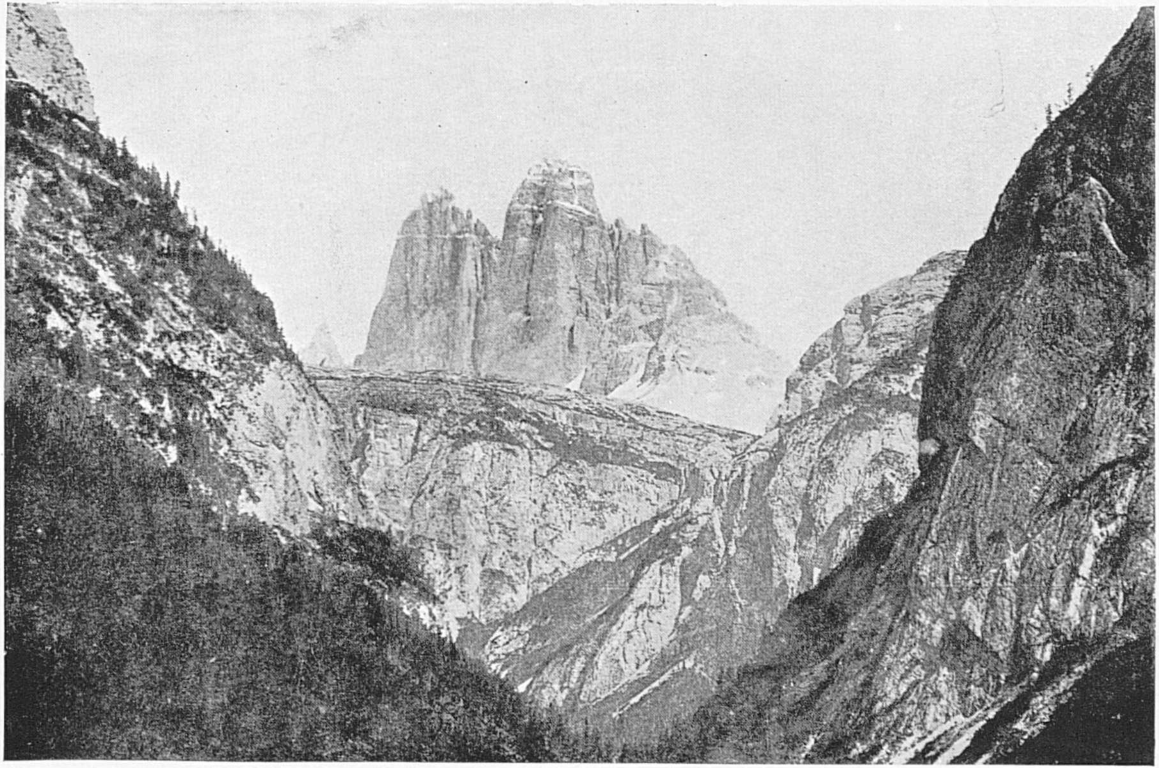
FIG. 6.—BEDDING AND JOINTS IN DACHSTEIN DOLOMITE (DREI ZINNEN).

[1] The Schlern Dolomite is about the age of the Red (Keuper) Marls of England; the Dachstein belongs to a group poorly represented in our own country, which intervenes between the Keuper and the Lias.

to a great altar of sacrifice;[1] the Pelmo and the Tofana rise in mighty crags, crowned with comparatively inconspicuous summits. But the ordinary type of a dolomitic mass in the Italian Tyrol is a huge curtain wall with broken battlements and ruined towers. Such is the wonderful range of the Rosengarten, which we can watch from the streets of Botzen as it kindles into a strange glory of sunset colours. Such also is the huge fastness of the Langkofl, near Campidello. Perhaps from no place in the Alps can two more striking views of rock scenery be obtained than from Landro on the Ampezzo road. Across the little Dürren See, reflected in its placid waters, rises the great rock wall, crowned with ruined turrets, of the Monte Cristallo; and we have but to walk a short distance farther along the lake shore to see up a side valley the yet stranger forms of the Drei Zinnen—the Three Battlements, as they are so appropriately named. Two of them rise sheer above their rocky base for hardly less than 3,000 feet. Not the least charm of the Dolomites, though the remark applies more or less to all the limestone Alps, is the combination of the grandest crag scenery with foregrounds hardly less luxuriant than an English park. Two of these views, beyond others, have impressed themselves on my memory; one being that from a meadow near Count Welsperg's Jagdschloss in the Primiero Dolomites.[2] Passing the

[1] "The Dolomite Mountains," p. 158, where the mountain is called Geiselstein.

[2] Count Welsperg, according to Gilbert and Churchill, was a retired cavalry officer in the Austrian service, who had built himself



From a photo by] [*Herr Anton Gratl, Innsbruck.*

8. THE DREI ZINNEN.

To face p. 100.

ruined castle of Pietra, so strangely perched on a crag, solitary and now inaccessible, we enter a pine wood, from which, in a short time, we unexpectedly emerge. The wild crags which only a little while before we had seen rising around the floor of the glen, might well have led us to expect this to be nothing better than a chaos of rock and débris, but we find ourselves standing on the edge of a meadow,

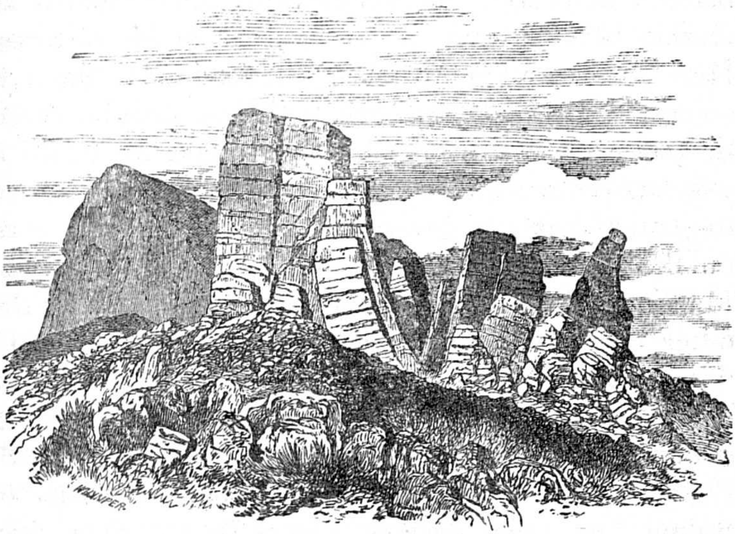


FIG. 7.—DOLOMITE MASS IN RUINS (CORTINA DISTRICT).

so green and level that it might be in Sussex or Dorset, but enclosed by a silent army of pines—taller, more slender, perhaps yet more graceful, than those of the Central and Western Alps—beyond and above which towers the rocky fortress of the Sass Maor.

a small house on this secluded spot, near the home of his ancestors. But as I have not seen the place since 1880, it no doubt has now another owner.

The foreground is a gem of sylvan scenery; in the background "the giant dolomites stand round like pillars of the sky, where the jackdaws chatter, and the eagle screams."[1] Not less striking as a contrast, and not limited to so small an area, is a part of the valley leading down from the Tre Croci Pass to Auronzo. The scene was probably familiar to Titian, for he was born at Pieve di Cadore, some dozen miles below that village, and memories of the dolomites, as Ruskin tells us, may be recognised in his pictures. Here, as I record in my notes, "the road led us through scenery which was like a park, for it was often bordered by pines, so well grown that they might have had a woodman's care, and these here and there gave place to gentler slopes of green sward. Behind these rose on the one side the magnificent cliffs of the Croda Malcora and the pinnacles of the Marmarolo; on the other the crags of the Cristallo and Campoduro." These two views are, in my opinion, the best of their kind among the compact coherents; but we obtain the contrast of great limestone cliffs with slopes of green alp and purple pine, perhaps of walnut and other deciduous trees by the river side, in every part of the Alps where rocks of this kind are developed on a grand scale, from the border of Provence to the heart of Carinthia.

[1] Gilbert and Churchill, "The Dolomite Mountains," p. 449.

CHAPTER V

DISTRIBUTION OF SNOWFIELDS AND GLACIERS IN THE ALPS

At a certain elevation on a mountain range, provided it be sufficiently lofty, the snow which falls during the colder part of the year is no longer melted away during the warmer one. This is called the snow-line, and its position, if we compare snow with income, shows where receipts begin to be greater than expenditure. Thus its height will mainly depend on the mean temperature of the region, and will gradually rise above the sea-level as we pass from polar to tropical regions. It cannot exist on ranges where the mean temperature even at the crest exceeds 32° F. Its position, however, is not wholly determined by the average of solar heat; it is affected by several minor causes, and in any case the snow-line corresponds with a temperature slightly under 32°, because a snowbed suffers some loss by evaporation even during a long frost. Variations are also due to the aspect of the slope, the nature of the ground on which the snow has fallen, the structure of the mountain side, and other causes, which though of minor importance cannot altogether be neglected.

We need only glance at the north-eastern face of the Matterhorn, every crag of which is well above the line for that part of the Alps, to see that it mainly consists of bare rock. The reason is obvious. The greater part of this pyramid is too precipitous to allow the snow to rest. I have seen it once or twice, after bad weather, white from head to foot, but this chrism robe soon disappears under the rays of the sun, and before the end of a second day only a few steep patches are left clinging permanently to the cliffs. We may take it as a rule that in the Alps, as in other temperate regions, every mountain face which exceeds a certain steepness will be free from permanent snow, except where seamed by gullies or interrupted by ledges. Again, the aspect of a slope must obviously make a great difference. If it faces to the north it almost never receives a ray from the sun; if to the south, it basks in the full blaze of the noontide radiance; thus, without discussing other disturbing causes we need not hesitate to say that in the Alps, as in other mountain regions, we cannot attain to more than a general accuracy in any statements about the height of the snow-line.

The chain also extends over at least 4° of latitude, which means a difference of 9° F. in the mean temperature of extreme positions at sea-level; or that, other things being alike, the southern snow-line would be quite 2,700 feet higher than the northern. The difference also in longitude of its western and eastern ends is nearly 11°, so that at the one the climate is more of an oceanic, at the other of a continental type, which affects the amount of snow, both received and expended. The effect also of a large area of exceptionally elevated ground, such as the High Alps of Dauphiné, is to lower the snow-line in its immediate vicinity. Partich's method of obtaining the height of the snow-line [1] is to tabulate the lowest points or ridges which are permanently snowclad and the highest which are similarly bare, and take the mean of the two. But this obviously is very laborious, and must involve difficulties in dealing with snow in clefts and other sheltered positions, so that we may have to be content with statements which are not more than roughly accurate. The height of the snow-line, according to Hann,[2] in the Middle and Western Alps (lat. 46° ; say, Zermatt) is 8,858 feet; in the Central Tyrol (lat. 47° ; say, the Brenner Pass), 9,252 feet, and in the Hohe Tauern (farther east along the same parallel), 9,353 feet. If I may venture to oppose my experience to the results of statistics, I should regard these statements as slightly in excess, and think we should not be far wrong in putting it at about 8,000 feet in the mountains more immediately north of the Rhone Valley and about 8,500 feet for those to the south of it. In the Graian and the Dauphiné Alps, the snow-line of course is higher, but I doubt whether, even in the latter, it attains 9,000 feet.

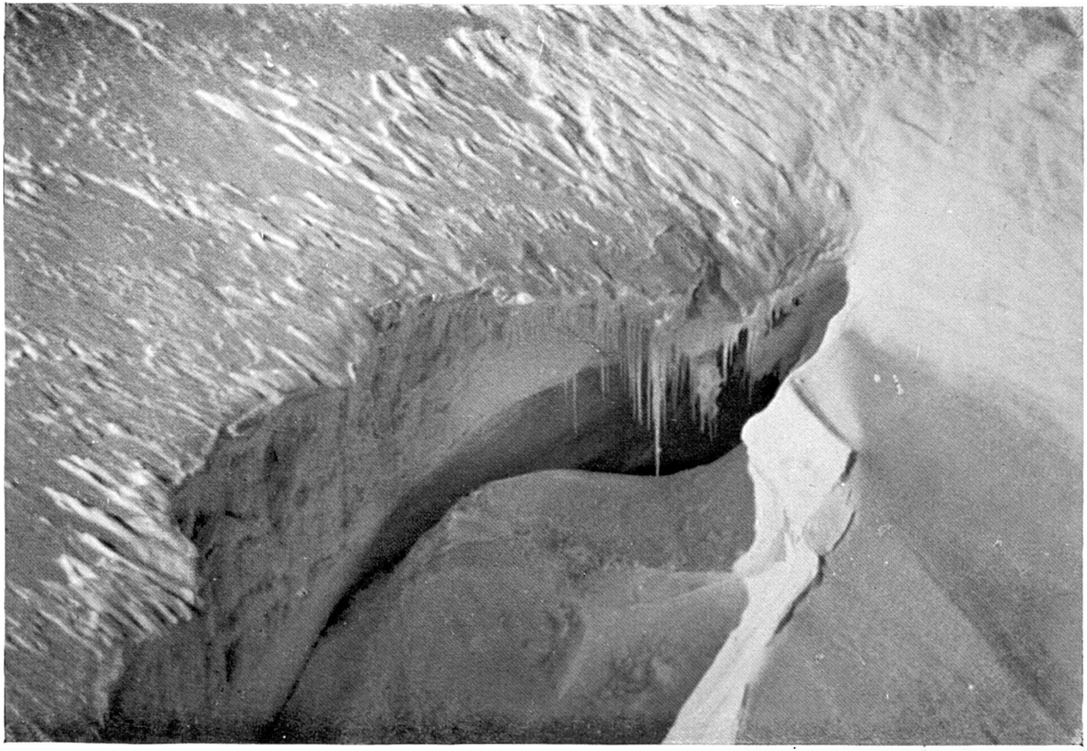
Glaciers do not form till a higher level is reached, and in this case the configuration of the ground is more than ever important. As a rough estimate, I should place the glacier-generating limit about a thousand feet higher than the snow-line. But here also a precise statement is even less possible, for there is no abrupt passage from a bed of permanent snow to a glacier.

[1] Applied by V. Paschinger to the French Alps. *Zeitschrift für Gletscherkunde*, January, 1911, quoted in the *Geographical Journal*, vol. xxxviii. p. 210.

[2] *Handbuch der Klimatologie* (1883), p. 196.

In such a bed the lower part is converted into ice, to some extent by pressure, but still more by a melting at the surface and the water freezing again as it is percolating downwards. The great snow slopes, which cling to all but the steepest parts of the higher peaks, though the avalanches discharged from their surfaces help in feeding the glaciers which are forming in the valleys immediately beneath them, are not, strictly speaking, glaciers. The snow of which these slopes consist is fast frozen to the rocks, and is parted by a deep fissure called the *bergschrund* from the névé, firn, or supply basin of the glacier. In the latter also the snow is frozen, but it is moving, though very slowly, and is thus torn away from the former, which is at rest. This névé, however, at any rate in the upper part, is not yet glacier ice, the change from the one state to the other being slow, and, as we shall presently see, in some way dependent on the motion of the mass, which is more rapid in the glacier as it is descending a valley, than in the broad supply basin of the névé, just as would be the case with a stream and the tarn from which it issues. Probably, indeed, the ice in a glacier undergoes more than one change in structure before it finally melts; but this question, and the physical cause of the movement, we must leave for the present.

The névé, as we can see from an examination of the walls in one of the great rents by which it is occasionally traversed, has a distinctly bedded structure, being built up of successive layers which indicate distinct periods or seasons of snowfall; the glacier consists either of clear, solid ice, resembling that formed on a lake during a prolonged frost, or



From a photo by] [*Dr. Tempest Anderson.*

9. BERGSCHRUND OF A GLACIER.

To face p. 106.

of alternating bands of this and a more porous whiter kind. To this structure also we must return, but it may suffice at present to point out that all stages exist between a bed of frozen snow and a true glacier; the intermediate being exhibited in glaciers of the second order, as they have often been called. These, as Principal J. D. Forbes observed, perish soon, because their collecting basins are small. "The amount of overflow, or the discharge of the glacier—upon which depends the extent of its prolongation into the lower valleys—depends in its turn on the extent of the névé or collecting reservoir." [1] Thus, no true glaciers are now to be found in the Cottian Alps, though Monte Viso rises to a height of 12,609 feet above sea-level, and permanent snow-beds, as we can see on passes near its base, exist at a level of 9,000 feet or even a little below it. But so steep are its crags and slopes that the snow can only cling to these; nowhere is the head of a valley both large and elevated enough to give birth to a glacier. In other parts of the Alps, glaciers may exist in one part of a range and be absent from another. For instance, in the Graian Alps, south of Aosta, the rocky pyramid of Mont Emilius attains a height of 11,677 feet, and looks down upon glens, the heads of which are quite 9,500 feet above sea-level: yet in these the glaciers are at most only of the second order, while on the southern side of the Cogne valley even the Col della Nouva, though only 9,623 feet in height, is approached by a glacier which, though small, is more normal in character; while farther to the west, owing

[1] J. D. Forbes, "Occasional Papers on Glaciers," p. 244 (1859).

not only to the greater elevation of the adjacent peaks, but also to the configuration of the higher regions, a considerable amount of ice must be traversed to reach either the Col de Monei (11,247 feet) or the Col de Grandcroux (10,844 feet); the glacier from the latter descending to a comparatively low level. In fact, all the great glaciers in the Alps are born on the gentler slopes and cradled in the basin-like heads of the valleys among the higher peaks. Of this no better illustration can be found than the Great Aletsch Glacier, which is the largest in the Alps, being about 16 miles in length, and for the greater part of its course about a mile and a quarter in width. Here, from a central point, near the well-known Concordia Club hut,[1] "in what has been happily called the Place de la Concorde of Nature, four snow valleys diverge at right angles." The one running southward is the channel of the effluent ice-stream. "That leading N.W. to the Jungfrau Joch, called the Jungfrau Firn, is naturally considered as the principal source of the Aletsch Glacier, as being in the same line with the main channel by which the traveller has ascended. To the S.W. an avenue of névé, equal in dimensions to the main stream, ascends by a gentler slope to the Lötschen Lücke. In the opposite direction, or N.E., the Grünhorn Glacier mounts by a rather shorter and steeper inclination to the Grünhorn Lücke, connecting the snow-basin of the Fiesch Glacier with that of Aletsch."[2] Between these

[1] There is now also a little inn, the height being 9,416 feet; so that more comfortable night quarters can be obtained than in the old days when the Faulberg Cave was the only possible shelter.

[2] "The Alpine Guide: the Central Alps," part i. p. 104 (1907).

highways rise some of the most elevated peaks in the Oberland—the Aletschhorn and the Jungfrau, the Mönch and the Gross Fiescherhorn—all of them exceeding 13,000 feet in altitude. The glaciers also from the Aiguilles to the east of Mont Blanc are much shorter on the southern than on the northern side, because of the greater steepness of the former, and the same rule holds good of the Pennines generally and in the Bernina. The difference in aspect also co-operates, but we must not forget that in the Central Oberland the bigger glaciers are on the southern side of the watershed.

As the glacier-generating line is about a thousand feet above the snow-line, it will probably correspond roughly with the isotherm of 27°. But, as I have already said, other circumstances may make this necessary condition inoperative, so that the Alpine glaciers are rather irregularly distributed. To enumerate all, to which this title may fairly be applied would be little better than compiling a catalogue of names, so I shall restrict myself to mentioning the more conspicuous. According to A. Heim's valuable memoir[1] they number, with those of the second order, fully 1,150. Small glaciers occur on the Dachstein (9,845 feet) south of Hallstadt and the Uebergossene Alp (9,643 feet), a few miles to the west in the Berchtesgaden district, but they are hardly more than large snowfields, and the first of any importance are grouped around the Gross Glockner (12,455 feet), where the Pasterze[2]

[1] *Handbuch der Gletscherkunde* (1885), p. 49.

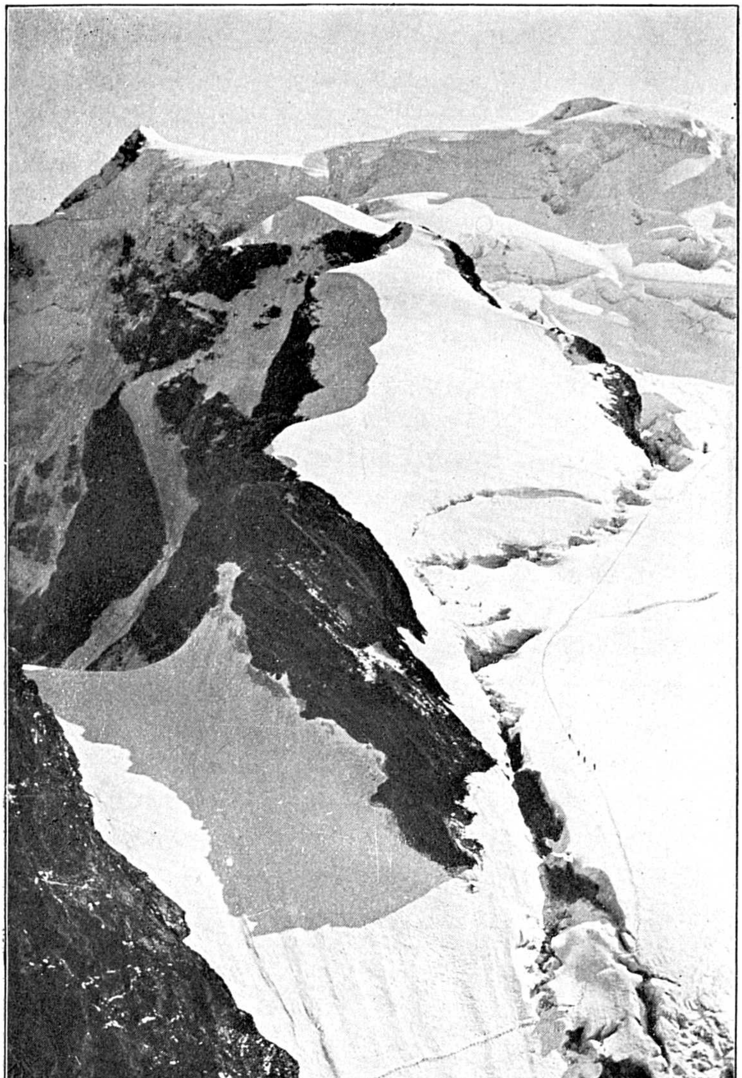
[2] The Gross Glockner rises at the side, not at the head of this glacier, and the view of it from near Heiligenblut in the opinion of the first editor of the "Alpine Guide" (J. Ball), "surpasses any-

Glacier is rather more than six and a quarter miles long.[1] Another, but slightly lower group, has for its centre the Gross Venediger (12,053 feet), which, though less lofty than the Glockner, is better adapted by its form for the development of icefields. These also are frequent but not large, in the slightly complex Zillerthal range, rather farther west on the central watershed, in which seven or eight of the peaks exceed 11,000 feet and a good many do not fall much below it. Beyond the deep gap of the Brenner Pass glaciers become more frequent. Those of the Stubayer range, the highest point in which attains 11,512 feet, are numerous rather than extensive, but a more important group clusters about the head of the Oetzthal, where the peaks twice surpass 12,000 feet in height. This group, according to Von Sonklar, includes over 230 glaciers, several of which are among the most considerable in the Alps. Perhaps the latter statement is slightly exaggerated, but the Hintereis is 6 miles long and the Gepatsch 6¼.[2] Slightly to the west of south, some dozen miles away across the upper valley of the Etsch or Adige, rises another and yet more impressive group of mountains, partly calcareous, the

thing of the same kind to be gained from any inhabited place, not reckoning the mountain peaks of Switzerland": a remark which I could not venture to dispute. There is a fairly good, though rather too "spiky," chromolithographic picture of this view as a frontispiece in Dr. A. Von Ruthner's pleasant "Berg und Gletscher-Reisen in den österreichischen Hochalpen" (1864).

[1] This and the subsequent statements about the length of glaciers are taken from the "Alps in Nature and History" by W. A. B. Coolidge (1908).

[2] W. A. B. Coolidge, *id.*, p. 351.



10. UPPER SNOWFIELDS OF THE ORTLER.

(From a photograph by Mrs. Aubrey Le Blond.)

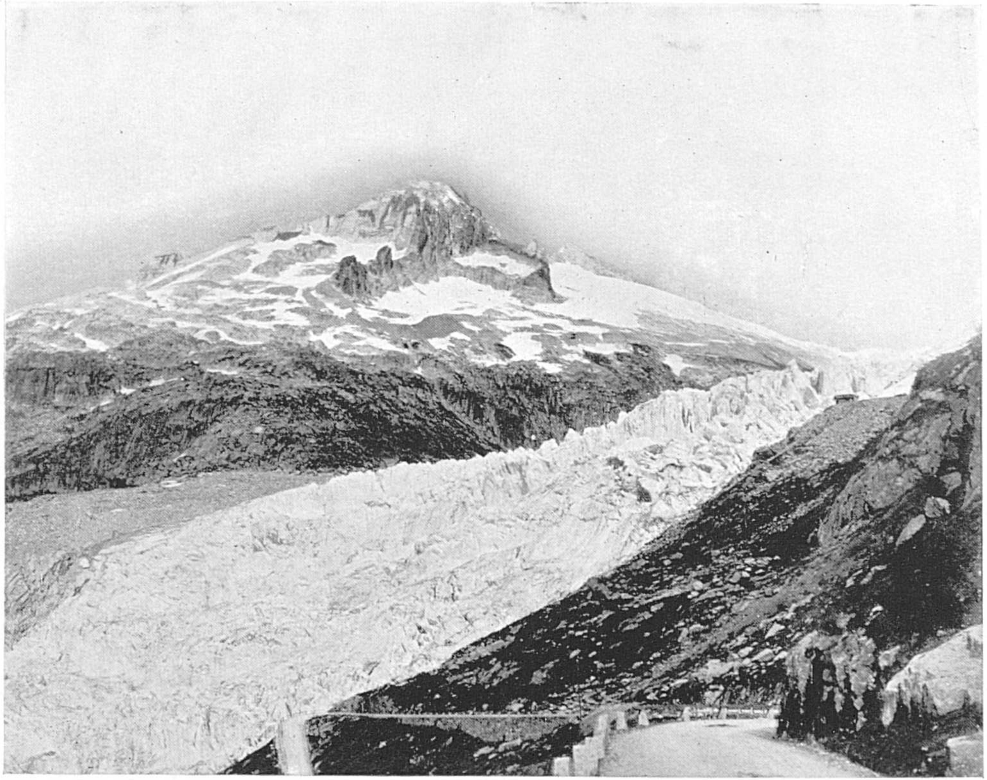
To face p. 110.

highest summit of which, the noted Ortler Spitze, is 12,802 feet above sea-level. The view of it from near the summit of the Stelvio Pass is one of the grandest afforded by any carriage road in the Alps. Another fine neighbouring peak, the König Spitze, is not quite 150 feet lower, and the glaciers are numerous, some attaining a considerable size. The mass consists of four or five spurs radiating from the Monte Cevedale (12,343 feet); for the Ortler itself lies on the north-western of these, some distance from the centre. A few miles away to the south, on the opposite side of the Tonale Pass, is the fine group of the Adamello, which has been already mentioned. In the Dolomite Mountains, south of the central watershed, only one glacier claims even a passing notice, that on the northern side of the Marmolata (11,024 feet), and it does not actually descend into a valley.

Proceeding westwards from the above-named group we find small and scattered glaciers becoming more numerous as we approach the eastern border of Switzerland, but the first really large icefields occur in the Bernina group, of which the highest peak just surpasses 13,300 feet, and several exceed 12,000 feet. The Morteratsch and the Roseg, on the northern side, are fine specimens of valley glaciers, and the Palü, though inferior in size, is remarkably beautiful. On the southern side the glaciers, though fed by extensive snowfields, are distinctly less important, and so are those on the Monte Disgrazia, which, though only a little more than 12,000 feet above the sea, looks every inch of its height owing to its comparative isolation. Though scattered glaciers are numerous west of the Upper Inn, hardly any are remarkable till we reach the valley of the Reuss. Its comparative isolation gives a certain dignity to the Piz Valrhein, and the Tödi, a grand limestone mass, which rises to a height of 11,887 feet, is the culminating point of a rather scattered group of icefields, among which the Biferten Glacier, which descends from the Tödi itself towards the Linththal, and the Hüfi Glacier, draining into the Reuss through the Maderanerthal, are the most important.

Between the passes of St. Gotthard and the Simplon, the glaciers, until we approach the latter, are small and scattered; for the Blindenhorn is the only point in the range, which slightly exceeds 11,000 feet. From it the principal glacier—the Gries—which is about four miles in length and nearly one mile in width, takes its rise. This is chiefly interesting because one part of it is so even as to be crossed by the track to the Gries Pass (8,098 feet), which is easily traversed by beasts of burden, and according to Dr. Coolidge [1] is doubtless the route by which the still-existing German-speaking colony came into the Val Formazza in the thirteenth century. It also served, in combination with the Grimsel, for the transport of merchandise between Italy and the Bernese Oberland, and continued to be an important commercial route till after the earlier part of the sixteenth century, when it gave place to the Antrona Pass, between Saas and Villa, in the Tosa valley south of Domo d'Ossola, both of which routes were practically superseded by the Simplon Pass.

[1] "The Alps in Nature and in History," by W. A. B. Coolidge, p. 172.



From a photo by] [*Mr. J. J. Lister, F.R.S.*

11. ICEFALL OF THE RHONE GLACIER.

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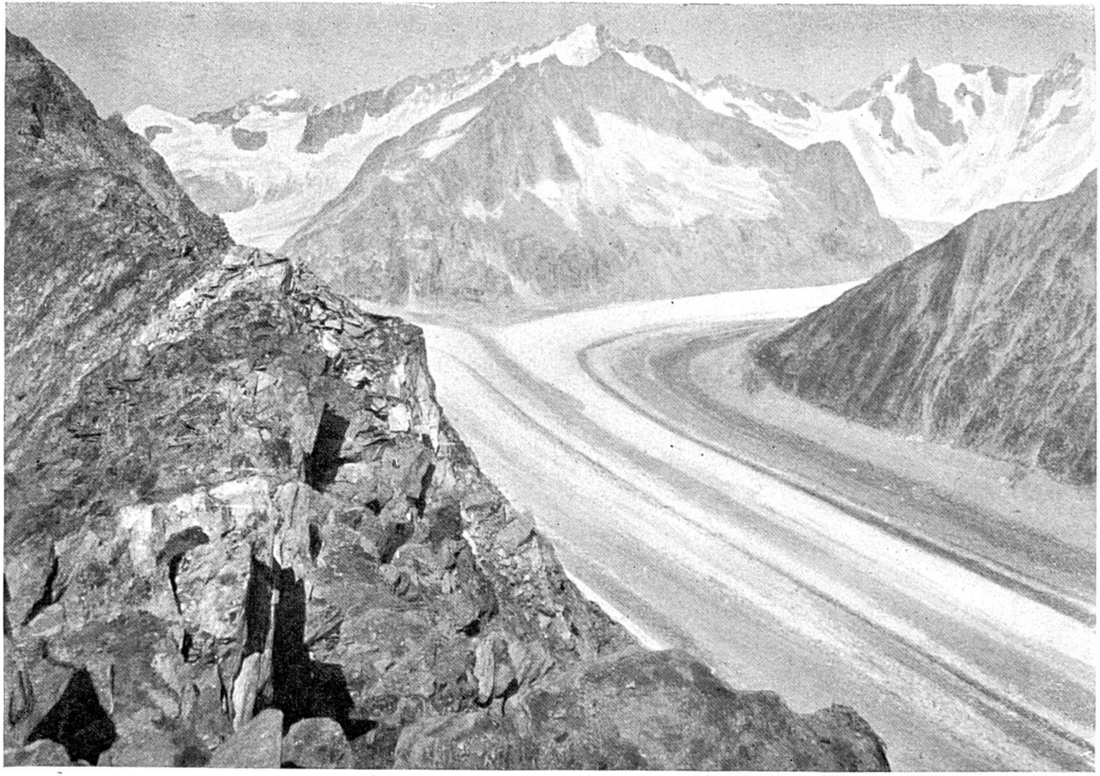
But on the western side of the glen down which the Reuss hurries on its way to the Lake of Lucerne, we come to one of the great glacier regions—the giant range of the Oberland. Its eastern outpost—for this is severed from the main mass by the valley of the Aar and the comparatively low pass of the Grimsel (7,100 feet)—is the group of peaks around the Stein Alp Glacier, known collectively as the Sustenhörner, and those others, north of the Furka Pass, where the Galenstock (11,802 feet) overlooks the great ice-stream of the Rhone glacier. North of this, and just severed from the first-named group by the gap of the Susten Pass, is the snowy ridge culminating in the Titlis (10,627 feet), and the Gross Spannort (10,506 feet), two fine masses of snow-capped limestone crags; and yet farther north is the not less grand, though lower (9,620 feet) mass of the Uri Rothstock. Across the glen of the Upper Aar, as if to compensate for the lowness of the Lepontine range—the watershed of the chain—rises the great *massif*, commonly called the Bernese Oberland, the peaks of which are not often surpassed in height, nor the glaciers in length, by any part of the Alps, for the Finsteraarhorn just overtops 14,000 feet, and ten others lie between that elevation and 13,000 feet. Of its largest glacier, the Gross Aletsch, about 16 miles long, we have already spoken; but the Unteraar, in which branches from either side of the Schreckhorn unite to flow eastward as the source of the River Aar, is about 10 miles in length. The Fiescher Glacier is the same. The Oberaar Glacier also is by no means a small one, nor are the Ober and the Unter Grindelwald Glaciers (the latter 6¼ miles), which flow towards the north, nor the

Rosenlaui, the Gauli ($8\frac{1}{2}$ miles), and the Ober Aletsch Glacier, which must formerly have joined its larger neighbour in the neighbourhood of the Belalp.

At the western end the Lötschenthal pierces deeply into this great mountain mass of snow and ice. The southern arm culminates in the Bietschhorn (12,970 feet), one of the grandest pyramids in the Alps, and then rather quickly sinks down to the ordinary level; the northern one supports the extensive snowfield of the Petersgrat, which sweeps round the head of the Gasterenthal to the outlying Balmhorn and Altels, and looks across the Kander Glacier to the fine group of the Blümlis Alp, the highest summit in which is a little over 12,000 feet. Then the deep gap of the Gemmi Pass (7,641 feet) breaks the continuity of the snow range in the Oberland, which indeed has already been nearly severed on the eastern side of the Balmhorn by the Lötschen Pass (8,842 feet), connecting the Gasterenthal with the Rhone Valley by the Lötschenthal. Both these passes, according to Dr. Coolidge,[1] were known early in the fourteenth century; and as the latter of these, although a small glacier occupies its summit, presented no such formidable obstacle as the precipitous cliffs on the southern side of the Gemmi, all local commerce for long passed over it. But after a good path had been constructed up those cliffs, it once more became a lonely pass between two lonely valleys. Its name, however, has of late become familiar, for the great tunnel, constructed to shorten the route between northern Germany and Italy, has been carried beneath it. West of the Gemmi, the line of the Oberland

[1] *Loc. cit.*, p. 174.



From a photo by] [*Dr. Tempest Anderson.*

12. MORAINES OF OBER ALETSCH GLACIER.

To face p. 114.

range is continued by the insulated snowfields, with only small glaciers, of the Wildstrubel (10,673 feet), the Wildhorn (10,709 feet), and the Diablerets (10,650 feet).

Where the *massif* of the Oberland declines in importance, that of the main range begins to assert itself. Just east of the Simplon Pass, the snow-clad mass of Monte Leone, from which the Kaltwasser Glacier almost descends to the road, rises to a height of 11,683 feet, forming the eastern outpost of the great icefields of the Pennines. In the range immediately west of the Simplon, between that gap and the Saasthal, the glaciers are larger on the western than on the eastern side, where hardly one is of much importance. That is no doubt due to the fact that the great rock barrier—though its three principal summits, the Rossbodenhorn, Laquinhorn, and Weissmies, all overtop 13,000 feet—is generally very steep on this side. This barrier is, to a certain extent, isolated from the main group of snowy giants farther to the west, for its watershed nearer to the head of the Saasthal is crossed by the Antrona Pass (9,331 feet), once an important trade route, and the Monte Moro (9,390 feet), which, although never quite free from snow, together with the Ofen Pass of the same elevation, was often used before the days of carriage roads.

West of the Monte Moro begins a great group of mountains, which, if its glaciers are slightly smaller than those of the Oberland and its principal summit is overtopped by Mont Blanc, yields to neither district in the area covered by snow and ice or in the average elevation of its crests. Only in one place between the Monte Moro and the Great St. Bernard does its watershed sink below 10,000 feet (at the Col de Fenêtre—9,141 feet), and this cannot be crossed without traversing a glacier. But an army went over it in 1476 ; so did Calvin sixty years later, escaping to Aosta from his enemies ; and it was fortified, rather more than a century afterwards, to prevent the Vaudois refugees from returning to their homes.[1] Four important valleys, each bifurcating, cut back deep into the heart of this range, the highest peaks of which are grouped around their heads, the descents being steeper and the glaciers smaller on the southern side than on the northern. The westernmost of these peaks form a great loop which encloses the Zermatt Visp, and separates that river from the Saasthal branch, the two uniting at Stalden. Its eastern side is generally steeper than its western, but this, apparently, does not always determine the size of the glaciers. The Balfrinhorn (12,473 feet), so grandly seen from the neighbourhood of Visp, is its northernmost peak. To the south of this is the Ried Pass (11,800 feet), from which a long glacier descends towards the west, and none of any importance in the opposite direction. Then rises the long range of the Mischabelhörner, the three chief peaks of which, the Südlenz, the Dom, and the Täschhorn, fall but little short of 15,000 feet ; the second of these—the loftiest mountain entirely in Switzerland—attaining 14,942 feet. On the eastern side these peaks are very precipitous, but neither on it nor on the western are the glaciers remarkable for their volume. But from the Täschhorn southward a marked change

[1] Ball's Guide, "Western Alps," p. 439 (1898).

occurs in the structure of this spur and the distribution of its glaciers. It recedes somewhat to the west and they become larger on the eastern side. Its crest also is not quite such a continuous wall, and the separate peaks are, on the whole, less precipitous and more variable in form. Curving gradually and crowned by the snowy mass of the Alphubel (13,803 feet) and the less impressive cone of the Allalinhorn (13,236 feet), it throws out a spur northwards from the latter, so as to form a gigantic corrie, extending from the Südlenz Spitz at the one end to the Mittaghorn (10,330 feet) on the other. This shelters the great slopes of névé and masses of broken ice, which are often collectively designated the Fee Glacier. To this great mountain amphitheatre we must return, for it is also an exceptionally fine example of a so-called hanging valley. But all the glaciers on the western side are comparatively small. From the Allalinhorn the crest makes a similar though less pronounced recession to the west, running through the rocky block of the Rimpfischhorn (13,790 feet) to the graceful peak of the Strahlhorn (13,751 feet), where it ends abruptly over the great precipices which descend for some 6,000 feet to the Italian valley of Macugnaga, another peculiarity in mountain structure which must be discussed presently. On the eastern side of the above-named peaks is a huge névé, which feeds two ice-streams; the smaller and more northern of them, called the Hochlaub Glacier, being only separated in its lower part from the Allalin Glacier. This, in the memory of some now living, not only descended to the level of the valley, but welled up on the other side far enough to hold back the main torrent and form the Mattmark See, which in those days was larger in size and more attractive in aspect than at the present time. On the western side of this part of the crest the glaciers are, perhaps, a little larger than those farther north, and the united waters of the range from the Täschhorn to the Rimpfischhorn are carried to the Zermatt-Visp by a glen which exceeds in length its other tributaries.

The watershed of the Alps, south of the Strahlhorn, runs in one direction almost due east to the Monte Moro Pass, supplying the large Schwarzberg Glacier, which also not very long ago reached the floor of the main valley.

In the other direction its course is generally to the south-south-west, and its crest oscillates from about 11,500 to 12,500 feet. Its eastern side is a wall of rock, more than a mile in vertical height, on which no glacier of importance can find a footing; its western is covered by a huge sheet of névé. This at first is unbroken, but presently a rocky ridge emerging like a reef from a sea, rises a little abruptly to its highest point in the Stockhorn (11,595 feet), and extends through the well-known Gorner Grat (10,290 feet) to the Riffelhorn (9,617 feet), separating the great ice-stream of the Findelen Glacier from the still larger one of the Gorner, which is 9¼ miles in length. The former once descended nearly to the level of the main valley; the latter in 1860 was ploughing up the turf on the undulating meadows only two or three hundred feet above the level of Zermatt. But the Gorner Glacier brings down ice from much more than the comparatively low and limited part of the watershed already mentioned. The latter, about three miles distance from the Strahlhorn, rises abruptly to the huge mass of Monte Rosa, from which it sweeps away towards the west, streaming with glaciers, altogether six in number, which unite with the Gorner. Nowhere in the Alps can we find such a confluence of frozen waters. One descends between two rocky bastions from the two highest peaks of Monte Rosa, the Dufour Spitze and the Nord End; another and much larger one sweeps down between that mountain and the snowy slopes of the Lyskamm, the lowest point in the connecting saddle being not less than 14,033 feet above sea-level. Other contingents descend from the white-robed Twins, Castor and Pollux, and the long ridge of the Breithorn; and at last comes a not inconsiderable glacier which, besides receiving ice from the third of those mountains, also takes it from the subordinate crag of the Petit Mont Cervin and the immediate neighbourhood of the Théodule Pass, where this mighty wall of rock and snow and ice suddenly drops down to a little less than 11,000 feet above sea-level, after having nowhere fallen below 12,200 feet, and for some distance everywhere exceeded 14,000 feet. In no other part of the Alps is the average level maintained at such a height for so long a distance. For about three miles from the Théodule Pass the crest rises but little above 11,000 feet, after which it suddenly leaps up in the immense pyramid of the Matterhorn, but it supports on its northern side a very considerable field of névé, part of which supplies the comparatively small Furgg Glacier. A peculiar complication is now apparent in the orographic structure. We should naturally anticipate that from the immediate neighbourhood of the Matterhorn a spur would be thrown out northward to form the western flank of the Zermatt Valley. But instead of this the head of the Zmutt Glacier—one of the largest of its ice-streams, but in its lower parts the least impressive, because its surface is almost entirely concealed by débris—cuts far back into the range, and the watershed extends westward from the Matterhorn to the Dent d'Hérens. There the spur takes its departure, and sweeps round on the other side of the Zmutt Glacier before beginning its normal course towards the north. As a result of this we can cross from that glacier, either over the watershed into the Valpelline, or into the Eringerthal, or into the Einfischthal, the comparatively unimportant snowy hump of the Tête Blanche (12,304 feet), forming the knot-point between three separate valleys, so far as one exists. The crest of the spur then runs nearly north for some distance, overlooking tributaries to the Zmutt Glacier, one of which, the Schönbuhl Glacier, is of some importance, and then rises in the Dent Blanche (14,308 feet), one of the grimmest and greatest of these Alpine giants. A projection from this peak separates the upper glens of the Eringerthal, and the Einfischthal, while the crest of the spur turns for a little way to the east, where the Col Durand affords an interesting glacier route from Zermatt to Zinal. Beyond this, at the Ober Gabelhorn (13,364 feet), the spur resumes its northward course, forming a grand line of peaks, and culminating in the Weisshorn (14,804 feet), which, when regarded from any position on the east, north, or west, is perhaps the grandest pyramid of snow and rock to be found on the Alps. From its northern side a fine ice-stream, the Turtmann Glacier, descends into a comparatively short valley, bearing the same name, which is intercalated between the larger valleys of the Navigenze and the Visp. In fact, there is a curious similarity between the two great mountain spurs flanking the Zermatt branch of the latter river. Each is limited, apparently partially severed, at its southern end, in the one case by the Findelen, in the other by the Zmutt Glacier; in each the culminating points, the Mischabelhörner and the Weisshorn, stand well to the north, while the Ried Glacier in the one corresponds with the Turtmann Glacier in the other.

The snowy Grand Cornier (13,022 feet) projects northward from the Dent Blanche to form the starting-point of the spur which divides the Einfischthal into two branches, sending down into the western and smaller of them the not inconsiderable Glacier de Moiry. Another great loop of snow peaks encloses the yet larger Eringerthal; a spur projecting northwards from its middle divides this also into two branches, of which the western is again the smaller. But none of the mountains on the southern and western side of this loop reach such elevations as do their neighbours farther east, few of their summits exceeding 12,000 feet. Their snowfields, however, are often extensive, and their glaciers important. But these, like others, have shrunk not a little during the last half century, and the most noted, the Arolla Glacier, has retreated along the bed of the valley to a greater distance from the old hotel. Its western tributary, the Vuibez Glacier, is connected by a broad snow saddle—the Col de Chermontane (10,119 feet)—with the long and rather level Otemma Glacier, which descends, nearly parallel with the watershed, to the Val de Bagnes, thus forming a kind of trough, which again threatens to sever the spur near its junction with the main range.

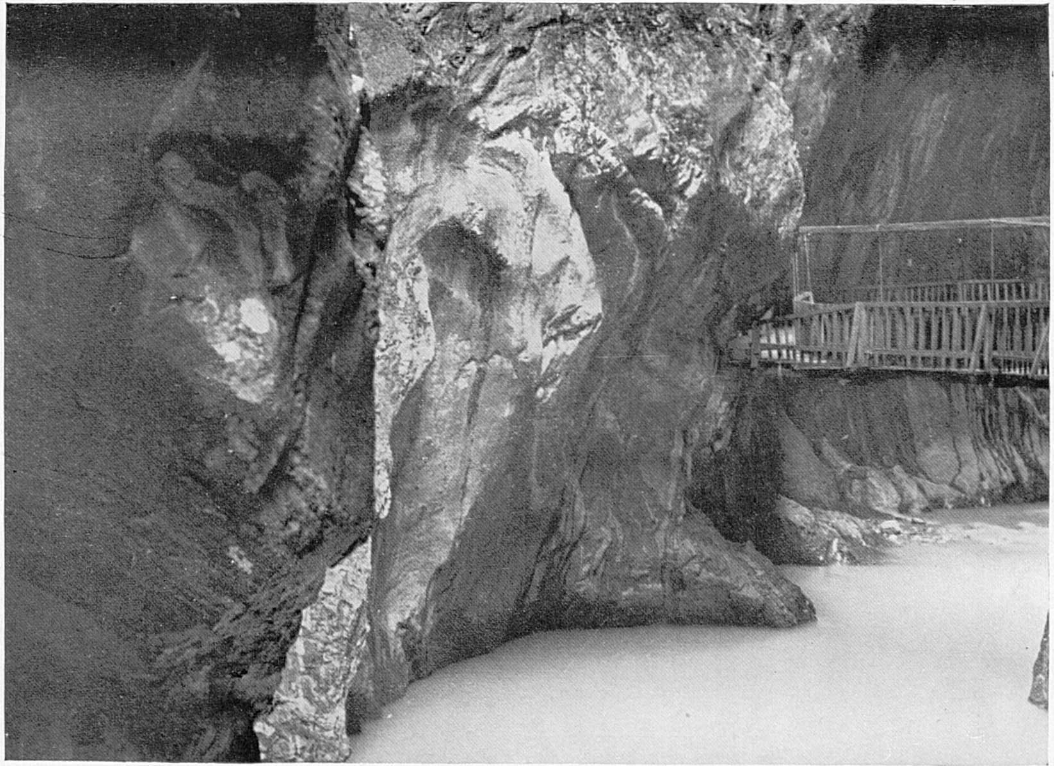
We have now arrived at the mountain group drained by the Dranse, which enters the Rhone at Martigny. Its physical geography differs in some important respects from that of its eastern neighbour. Its two main branches, the Val de Bagnes and the Val d'Entremont, unite at Sembrancher, but the latter has been already joined at Orsières by a third one, which, as it drains some of the glaciers on the southern flank of the Mont Blanc range, and is parallel with its axis, is of orographic importance. A grand mountain block, teeming with glaciers, separates the first and second of these valleys, and in that also the highest summit lies distinctly to the north of the main watershed. This is the Grand Combin (14,164 feet), which surpasses every peak in the Oberland, and is only exceeded by three others—the Weisshorn, the Matterhorn, and the Dent Blanche—in the Central Pennines. From its snow-clad northern flank a huge glacier—the Corbassière—descends almost to the floor of the Val de Bagnes between two lofty ridges, the summits of which rise in some cases above 12,000 feet. As usual, the southern face of the Combin is the steepest, and the great glacier of the Mont Durand, running nearly parallel with the watershed, and leading up to two passes less than 11,500 feet in elevation, makes a severance in this spur similar to those already noticed. The main watershed also, which for some distance forms the right bank of this glacier, is rather deeply notched; the Col de Fenêtre (9,141 feet) being the first place west of the Monte Moro where a mule path [1] goes over the Pennines.

Nearly to the south-west of the Combin the glacier-clad mass of the Mont Vélan, rising to a height of 12,353 feet, brings to an end the great line of snowy peaks which we have been following from the last-named pass. As usual, no glacier of any importance occurs on its Italian side, but on the more northern, the Valsorey, leading to the Col of that name, and the Tseudet, unite with the Sonadon Glacier from the Grand Combin at the head of a glen descending to Bourg St. Pierre, on the well-known Great St. Bernard road. Between the Vélan and the lofty *massif* of Mont Blanc, a distance of about three miles as the crow flies, but much more when measured along the zig-zag line of the watershed, we find no glacier of importance, for none of the summits reach 11,000 feet, and the crest occasionally drops down nearly to 8,000 feet. But immediately beyond the depression of the Col Ferret, the range of Mont Blanc towers aloft in all its grandeur, crowned by magnificent peaks and streaming with glaciers. Two of large size, the Glacier de Saleinoz and the Glacier du Trient, send their waters to the Rhone, the one by the Dranse, the other through the famous gorge at Vernayaz; while a third, the Glacier du

[1] Formerly a small glacier had to be crossed on the Swiss side, but that, as the ice has retreated, is no longer necessary (Ball's Guide, "Western Alps," p. 442 (1898)).

Tour, drains into the valley of Chamonix, a short distance above Argentière. For some time the glaciers on the more eastern face of the range, south of the Col Ferret, are steep, but not very large, becoming quite unimportant in the neighbourhood of the Dent du Géant. Not so, however, on the other face, where the two largest in the range, the Glacier d'Argentière and the Glacier des Bois, descended in former days fully down to the level of the valley. The latter is the larger, for its total length is 9¼ miles, equal to that of the Gorner at Zermatt. The name just given applies, however, only to its steeper lower part; that magnificent causeway of "thick-ribbed" ice which extends from below the Montenvers to the meeting-place of its three great affluents, is the well-known Mer de Glace. Of these affluents, the one most to the west, which has the best claim to be regarded as the main stream, descends from the noted pass of the Col du Géant[1] (11,060 feet), and is flanked on one side by the crags extending from the Mont Maudit (the first outpost on this side of Mont Blanc) to the Aiguille des Grands Charmoz; on the other by a large spur from the Dent du Géant. The semicircle of splintered peaks between this spur and the Aiguille Verte is drained by two fine ice-streams, the Glacier de Léchaud and the Glacier de Talèfre. Both these, as well as the upper part of the Glacier du Tacul, descend rather steeply, and thus are broken into

[1] On this pass De Saussure encamped for seventeen days, making observations. "In spite of all that has been done in modern times, no more striking proof has ever been given of persevering devotion to the cause of natural science" (Ball, *ut supra*, p. 365).



From a photo by] [*Dr. Tempest Anderson.*

13. GORGE OF THE TRIENT.

To face p. 124.

grand séracs. The last, indeed, has been compared to the foam of ten Niagaras placed end to end and stiffened into rest, a phrase which to those who have seen it will hardly sound exaggerated. The view from the upper part of the Mer de Glace may well contend for the prize of beauty with that from near the Concordia Hut in the Bernese Oberland.

From the snowy cowl of Mont Blanc, as might be expected, large glaciers radiate. On its northern side those of Taconnaz and the Bossons transport the snows which have accumulated between the two spurs extending from the base of the Calotte in the one direction to the Aiguille du Midi, and on the other to the Aiguille du Goûter. On its southern side the magnificent Brenva Glacier descends from a lofty recess a little east of the actual summit, and it once reached down to the stream of the Doire above Entraigues. On the western side of the summit four glaciers contribute their waters to that river, but only two of them actually unite with the great trunk stream of the Miage Glacier which descends from the watershed on the western side of Mont Blanc itself. This leads to a fine pass, only 11,077 feet in height, and overlooking a rock wall, at the foot of which is another and smaller Miage Glacier, which sends its waters by St. Gervais to the Arve. Yet farther away to the south-west the last high peak in the range, the Aiguille de Trélatête (12,832 feet), gives rise to two considerable glaciers, the larger of which, bearing the same name, takes a more or less westerly course and "balances that of Trient at the N. extremity of the same range." [1]

[1] Ball, *ut supra*, p. 377.

At the Col du Bonhomme (8,147 feet), on the watershed between the affluents of the Arve and the Isère, the gigantic range of the Western Pennines sinks to comparative insignificance, and though its axis of crystalline rock may be traced into Dauphiné, it is not sufficiently elevated to maintain even a snowfield of any importance. The main watershed of the Alps, separating the upper waters of the Doire from those of the Isère, also continues to be rather low for some distance to the south, and at one place, where crossed by the well-known pass of the Little St. Bernard, is only about 7,179 feet above sea-level. But this pass marks off a long region on either side of the Alpine watershed. The eastern half consists of the long spur called the Graian Alps; the western (sometimes bearing the same name) is more commonly known as the Tarentaise Alps. Some fine snow peaks and fairly large glaciers are found in the former region; the one rising either from the crest or a little north of it, the other almost always on that side. These peaks and snowfields may be said to have two centres; one formed by the massive Grand Paradis (13,324 feet) with the noble pyramid of the Grivola, also just surpassing 13,000 feet, which has snow on the two northern sides and steep rock on the two southern; the other is a cluster of peaks, exceeding 11,000 feet in height, which gives birth at its western extremity to the fine Rhèmes Glacier. The two snow regions are severed at the head of the Val Savaranche by an easy and comparatively low pass, the Col de la Croix de Nivolet (8,665 feet). The westernmost of these Graian valleys, the Val Grisanche, is bounded on that side by the main watershed of the Alps, on which rises the insulated mass of the Rutor[1] with its coronet of peaks, the highest of which reaches 11,438 feet. This supports on its north-west side an extensive glacier, which formerly descended to the little Lac de St. Marguerite (7,940 feet), where blue crags of ice rose above the water—a small and even more beautiful rival of the famous Märjelen See. But since 1864 all has changed; "the lake is now simply a big, dirty pond, with a moraine-besmirched glacier near it."[2] The mountain itself commands a view which is hardly surpassed from a point of similar altitude in any part of the Alps. South of the Rutor, the watershed of the Alps again sinks, though twice or thrice it nearly reaches, or a little exceeds, 11,000 feet, and is crossed at one place by the Col du Mont (8,681 feet), an old mule track, on which in 1794 there was some fierce fighting between the French and the Piedmontese.

Snowy peaks, however, are again conspicuous where the watershed between France and Italy curves a little to the east around the head of the Val Grisanche. The highest peak in the group, the Grande Sassière, rises to 12,323 feet, and fine glacier passes lead from Tignes in the Isère valley to the Val Grisanche, to the Val de Rhêmes, and to Ceresole on the southern side of the eastern Graians. The last-mentioned pass, the Col de la Galize, though 9,836 feet in height, claims the distinction of being "one of

[1] The name formerly was generally written Ruitor.

[2] Ball, *ut supra*, p. 289. A watercolour by the late Elijah Walton, representing the condition of the ice about the above-named date, belongs to the family of the late W. Mathews, one of the earliest explorers of this district, and I have a rough sketch which I made in 1864.

the very few glacier passes between the Mediterranean and the Great St. Bernard which are certainly known to have been traversed" so early as the sixteenth century.[1] At the present day it is crossed often by the country people with flocks of sheep, and sometimes by smugglers. A short distance farther south, where the crest of the Alpine watershed is again a little depressed, we find on the west of it the Col du Mont Iseran (9,085 feet), leading from the head of the Isère valley to a place not far from that of the Arc. This may be taken as the division between the Eastern and the Western Graians, and though without snowfields or glaciers of importance in its neighbourhood, it is not without interest as having been for long the haunt of a gigantic but mythical snow peak, the Mont Iseran. This was mainly the creation of certain cartographers, who apparently transferred the Grand Paradis from its proper position to one some fifteen miles away, on the other side of the frontier between Italy and France. Its ghost was exorcised by Mr. W. Mathews[2] in 1859, and finally laid by Mr. J. J. Cowell[3] in 1860. The Mont Iseran is only a pass (9,085 feet), quite an ordinary mountain track, not far from which is a rocky hump, the Signal d'Iseran, which is 10,634 feet in height.

The Western Graians or Tarentaise Alps do, however, contain some fine snow peaks, surrounded by fairly large glaciers. Near the north-east angle of the

[1] Ball, *ut supra*, p. 276.

[2] "Peaks, Passes, and Glaciers," series ii. vol. ii. p. 354.

[3] "Vacation Tourists and Notes of Travel in 1860," p. 261. A careful epitome of the story is given by Dr. W. A. B. Coolidge in Ball's Guide (*ut supra*, pp. 230–32). The name "Mont" is, in the Alps, often applied to a pass.

district is the ridge of the Mont Pourri, which culminates in a graceful pyramid, 12,428 feet above the sea, well seen in descending from the Little St. Bernard. The axis of the Tarentaise, if the term be permissible, continues from it in a tortuous direction towards the south-south-west, and on this, almost without an exception, the other glacier centres are situated. The highest of them is the Grand Casse (12,668 feet above sea-level), but the most extensive ice-clad area bears the collective name of the Glaciers de la Vanoise, the culminating point of which is the Dent Parachée (12,179 feet). Another line of snow peaks, with occasional glaciers, extends, with more or less interruption, along the main watershed southwards from the Col de Galize to the Roche Melon. Among these are the Levanna, which is but little below 12,000 feet, the Albaron and the Ciamarella which rise a little above it, and the Pointe de Charbonel, the monarch of the district, situated at the end of a long spur projecting to the north-west from the frontier range. Peaks above 11,000 feet are fairly numerous, and so are glaciers, though most of them are small. That on the snow-capped Roche Melon is crevassed enough to oblige the pilgrims, who annually seek its summit, to make a very considerable détour. Rising to a height of 11,605 feet, this is probably the highest sacred mountain in Europe. It has long enjoyed its reputation, for a bronze triptych, which was once preserved in the chapel on the summit, but is now carried thither in solemn procession from the cathedral of Susa, was first enshrined there, according to tradition, in the year 1358. On this elevated position Mass is said on

August 5th, the festival of Notre Dame de la Neige. A little west of the Roche Melon is the deep trench of the Mont Cenis (6,893 feet), beyond which the frontier watershed, though here and there, as around the Viso, supporting a snowbed, is free from glaciers.

For them we must look to the *massif* of the Dauphiné Alps, which is in reality a prolongation of the double, if not triple, crystalline axis of Mont Blanc. An outlying fold [1]—the Grandes Rousses—attains a height of 11,395 feet and supports a fair-sized glacier on either side of its double-headed ridge. But the great area of peaks and glaciers lies rather to the south-east where, as already described, it rises abruptly from a sea of lower mountains, and is linked to the range south of the Arc by the Col du Lautaret (6,808 feet), over which runs the high-road from Grenoble to Briançon. These peaks and glaciers form a great loop enclosing the mountain valley of the Vénéon, which takes a course to the north-west to join the Romanche at Bourg d'Oisans. Though the summits of this district are lower than those of the Pennine range, and its glaciers less extensive than the ice-fields of the Oberland, it surpasses every other part of the Western and Central Alps in the savage grandeur of its precipices and the almost fantastic outlines of its peaks. Two of these surpass 13,000 feet; at least seventeen lie between that level and 12,000 feet; many of its passes exceed 10,000 feet, and its glaciers, including those of the second order, are more than one hundred.[2] Of these the

[1] See p. 86.

[2] T. G. Bonney, "Outline Sketches in the High Alps of Dauphiné" (1865), p. xi.

longest are the Glacier Blanc and the Glacier Noir, which descend from its highest point, Les Ecrins (13,462 feet), but the singular sheet of névé, which is spread like a cloth on the huge block of the Mont de Lans, rising to about 11,700 feet and sending down short valley glaciers towards the north, may have a larger area. East of this glaciers extend along the craggy Meije (13,081 feet), the Ecrins, the Ailefroide, the Pelvoux, and other points, which it is needless to mention, though they are often comparable with any in the Graians. From the tabular mass of the Mont de Lans to the Col de la Muande on the opposite side of the loop, every part of the range rises well above 10,000 feet, and only those can cross it who have had some experience in mountaineering; but west of the latter pass the peaks become gradually rather lower and the ice-fields smaller. Here, with this solitary but mighty island of Dauphiné, the glacier-bearing regions of the Alps come rather abruptly to an end.

Of their importance as feeders of rivers it is needless to speak. As the ice melts during its descent into warmer regions, the water from its surface is engulfed, as will be described in the next chapter, forms a system of subglacial drainage, and finally emerges in a torrent, often large and strong, from a rude portal or cave (Fig. 9, p. 151). The Rhone, the Rhine, the Danube, the Po, and the Adige are the ultimate recipients of the rivers thus originated, and convey the waters from the snows of the Alps to the Mediterranean, the Black and the North Seas.

CHAPTER VI

THE MAKING AND MOVEMENT OF GLACIERS

In the Alps rain seldom, if ever, falls above a height of about 8,000 feet. All moisture is precipitated in the form of snow,[1] of which heavy showers may sometimes occur even in the middle of summer at a much lower level. After a spell of bad weather, I have often seen everything white down to 6,000 feet or even lower.[2] Thus snow accumulates on the higher mountains, though it has to pay tribute to the sunshine. When they are flat-topped, like the Alphubel or the Calotte of Mont Blanc, it is piled up to a considerable thickness; where they are sharp pyramids, most of it cannot rest for long. Here and there a thin layer may manage to adhere by being frozen to some face or edge, where it can just get a hold, but any more that falls slips off from the surface of the other as a powdery avalanche. But when the inclination is less steep, the new material may cling to

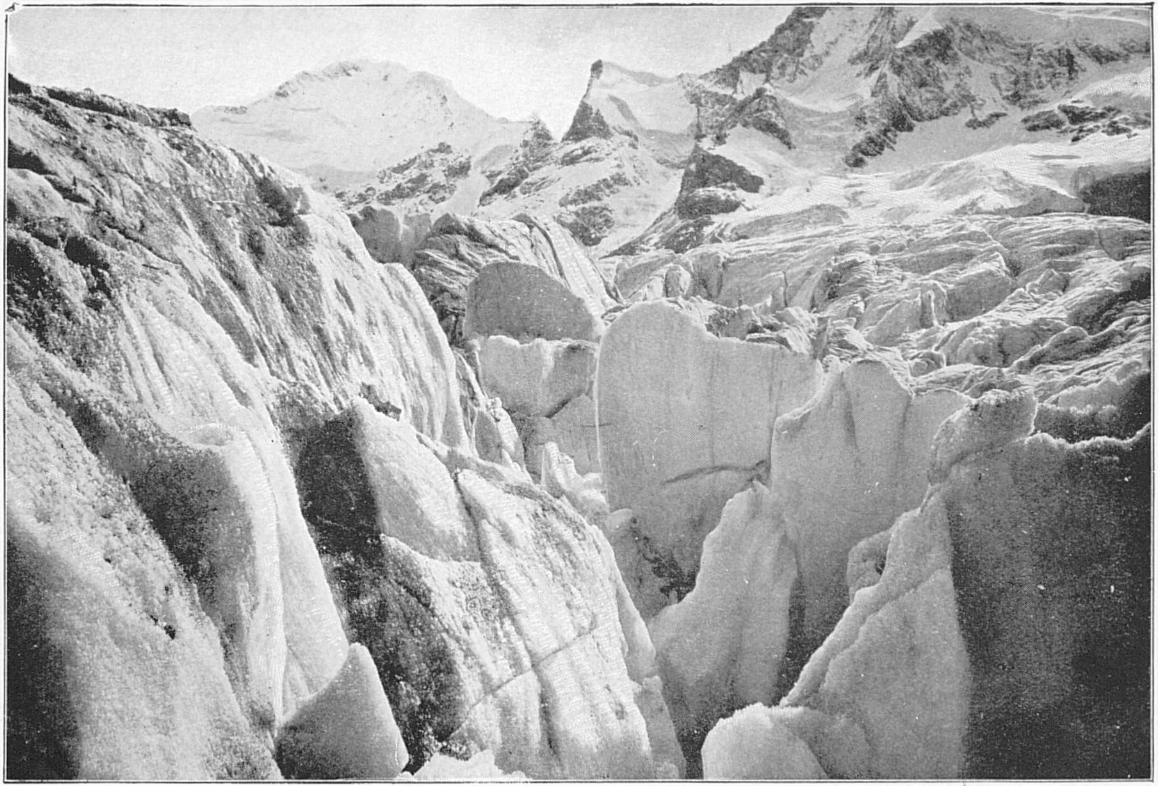
[1] Snow sometimes falls in tiny six-rayed stars, in which the spicular crystals of frozen water are grouped in fern-leaf patterns, but these can only be seen when the air is still; commonly they are broken up and driven together to form the irregular clusters with which we are familiar.

[2] I have seen snow falling heavily on a July night at Saas Grund (5,125 feet), and next morning it was lying on the grass in large clots less than 200 feet above the village.

the old, and a long, or perhaps a broad, snow-slope may be formed on the face of the mountain, which, however, may be forced to find relief in the same way after an exceptionally heavy fall. Such slopes often exist on the faces of pyramidal peaks, where they may be parted by rocky ribs or ridges, or may meet in a snowy edge. They also exist at the heads of valleys running back nearly to the crest of a mountain range. The floors beneath the cliffs of these valleys are often rather wide and nearly flat, on which the snow, of course, readily accumulates to form the upper snowfields of a glacier. We have only to glance into one of the deep chasms by which these are severed to perceive that they exhibit a regular stratification, bed being piled upon bed, each of which marks a more or less continuous deposition. These generally are not more than three or four inches thick, and have apparently followed one another, sometimes rapidly, sometimes with longer pauses, indicated by the presence of a thin layer of dust. They consist of frozen snow rather than of true ice, which is cemented together—in the upper part by the re-freezing of water percolating downwards from the melting surface, in the lower to a greater extent by the pressure of the superincumbent mass. The surface snow is usually the purest white, reflecting the sunlight from the tiny facets of its innumerable crystals, but the walls of the yawning chasm are an exquisite blue, which sometimes, like a turquoise, approaches green. Over their edges the snow curves in great cornices, and occasionally spans them with a fragile bridge, fringed in many places with icicles, which are not seldom several feet in length.

This part is the *névé*, or *firn*, of the glacier. Its material is in motion, and this, though very slow, suffices to break the continuity with the masses frozen to the steeper slopes above, so that a crevasse[1] opens out between the two, sometimes both wide and deep. The distance between the walls enclosing a névé basin usually becomes less as we descend, but the slope of the bed, at any rate for a while, more steep. Thus not only is the rate of movement increased, as when a stream of water issues from a lake, but the ice also is subject to pressure by passing through a narrower channel. That changes its aspect; the stratification seems to disappear, the material to become more homogeneous, *i.e.*, more like ordinary ice. But after some distance the glacier begins to exhibit a novel structure, to which the name of "veined structure" is often given. This consists of alternating bands, commonly less than an inch in thickness, of two kinds of ice, the one hard and blue, the other more granular and white. The structure is developed in weathering, for the first form projecting layers which must be broken with a hammer, while the second are often so disintegrated at the surface that they can be scooped out with the fingers. Both, of course, melt, though in a different way; for when the blue layers are more or less horizontal, they are found on examination to be pierced by small tubes, varying in thickness from a horsehair to about a twelfth of an inch, some going quite through, others only part way. These I suppose to be formed

[1] A chasm, or rent, in a glacier is called *crevasse* in French and *Schrund* in German. Such a one as is mentioned above is generally designated a *Bergschrund*, and is often a rather serious obstacle to the mountain-climber.



14. CREVASSES ON A GLACIER.

(*From a photograph by Mrs. Aubrey Le Blond.*)

To face p. 134.

by drops of water working downwards from the melting white ice in the overlying bed. I have also seen that when the beds of blue ice are in a nearly vertical position (as is not uncommon), fine cracks, generally about wide enough to admit the blade of a penknife, can be traced at their sides for some yards downwards. These may be very numerous, and they are sometimes enlarged to about an inch in width, when they are filled with water. To the action of this they are probably due, for that which is produced by the melting of the white ice may sometimes freeze again in percolating downwards along the blue layers and make them crack.

The cause of this veined, or ribboned, structure has been disputed, but the following facts are generally admitted. It penetrates the thickness of a glacier to a great depth; it is an integral part of its normal structure, extending, on the Unteraar Glacier, "from its lower extremity up to the region of the *firn*, or *névé*, . . . and the course was, generally speaking, strictly parallel with its length"; but near the lower end "the structure varies its position in a manner very difficult to trace satisfactorily, these becoming sometimes nearly horizontal." Principal J. D. Forbes [1] considered this structure to be analogous to the fluxional structure developed in certain lavas, more or less glassy, by the movements of a slightly differentiated mass, and a consequence of the nature of glacier ice, which he classed among the viscous substances. Professor Tyndall, however, maintained this structure to

[1] "Travels in the Alps," ch. xxi. See index in the edition of 1900 (W. A. B. Coolidge); also "Occasional Papers on the Theory of Glaciers," section xv., and the remarks on pp. 3–9, from which the quotations are taken.

be due to pressure, and comparable with slaty cleavage in a rock, pointing out that it was developed after the glacier had undergone much lateral pressure by being forced through a narrower part of the valley which it was descending, and he cited one or two instances where he found it cutting, almost at right angles, the stratification of the *névé*.[1] This explanation appears to me to present the fewer difficulties, but the difference between these two authorities was, perhaps, less than it seemed, for Principal Forbes calls attention to the analogy of the veined structure to slaty cleavage, which, however, at the time when he wrote, was vaguely ascribed to "crystalline or polar forces," an explanation with which, as he expressly states,[2] he was not satisfied.

This raises the question of the cause of glacier motion, over which, as it belongs to general physics rather than to the Alps in particular, and is one not less intricate than difficult, we must pass briefly. The explanations proposed fall into two groups, the one attributing the movement primarily to heat, the other to gravitation. Among the former, De Charpentier thought it was caused by the dilatation of water in capillary tubes which traversed the ice; Dr. Croll ascribed it to a melting and subsequent solidifying of the molecules of ice by the passage of heat through the mass; and Canon Moseley to an alternate expansion and contraction of the same from changes of temperature. Each of these explanations assumes that motion occurs

[1] "Glaciers of the Alps," part ii. section 27.

[2] *Loc. cit.*, p. 9. He returns to the subject at pp. 182 and 255. In slaty cleavage also a "shearing" movement of the particles is usual, if not universal.

in the direction of least resistance, and thus to a certain extent introduces gravitation; but the first has been abandoned on the ground that these capillaries are non-existent; the second requires a peculiar rhythmic change, which is most improbable; and the third, though very ingenious,[1] was supported by rather inconclusive experiments. In the other group, De Saussure ascribed the motion of a glacier to a simple sliding of the mass down the slope. His idea was rather vaguely expressed, but he perceived that the absence of acceleration distinguished the movement from that of a stone. Hopkins met this difficulty by showing that, if a glacier be regarded as a collection of large fragments rather than as one mass, and the slope do not exceed a certain angle, an unaccelerated movement may be produced by the melting of the ice in contact with the underlying rock. Forbes regarded glacier ice as a viscous substance, though much more solid than such things as honey. In fact, plastic would have been a better phrase than viscous, which has a misleading connotation. Tyndall, however, declared that ice too readily broke under strain and crushed under pressure for it to be classed with any substance truly plastic, and had recourse to Faraday's discovery of regelation: viz., that two pieces of ice, when brought into contact, promptly freeze together. Hence, the ice of a glacier is constantly broken by strain; the fragments, thus detached, slip downwards, come into contact with those in a lower position, and freeze to

[1] It was suggested by the fact that sheets of lead which had been placed on the roof of Bristol Cathedral had broken loose from their fastenings in consequence of expansion by day and contraction by night, and had moved downhill.

them. Thus a glacier as a whole "shuffles down hill" by movement of its constituent parts. But Tyndall's experiments to show that ice broke instead of bending under strain or stress, were, like those of Moseley, unsatisfactory, because, by neglecting the element of time, they failed to reproduce the conditions in nature. A stick of sealing-wax snaps when it is quickly bent, but if placed in a horizontal position, with one end supported, and left to itself, it takes a curved form. It was accordingly demonstrated by the late Mr. W. Mathews [1] that when account was taken of time, a slab of ice, if its ends were supported, also assumed a curved form. Of late years the subject has been further investigated, and it is now generally admitted that glacier ice is a viscous or, at any rate, plastic substance, though the exact cause of this property may not, as yet, be perfectly understood.[2] It moves, at any rate, as a fluid rather than a solid; the central part quicker than the sides, the upper than the lower. That was years ago demonstrated by Forbes, and confirmed by Tyndall and others. The rate of glacier motion in the Alps is, at a very rough average, nearly a foot a day. The mean movement of the Aar Glacier is 338 feet a year; of the Glacier du Bois 364 feet, of the Rhone Glacier 366 feet.[3] But

[1] For a lucid, critical account of the several hypotheses proposed and of this experiment, see *Alpine Journal*, iv. pp. 411–27.

[2] Some very important experiments with cobbler's wax, illustrative of the movements in a glacier, are described by W. J. Sollas in the *Quarterly Journal of the Geological Society*, vol. li. (1895), p. 361, and vol. lxii. (1906), p. 716.

[3] J. Prestwich, "Geology," vol. ii. p. 529. The great Greenland glaciers move much more quickly. Those producing bergs were estimated as moving 30 to 50 feet a day.

they cannot bear much strain; if the end broadens on level ground, it is rent by radial cracks; the retardation of the sides produces another set of crevasses oblique to the axis of motion; while any step or sudden steepening in its bed so shatters it as to produce an ice-fall. In the neighbourhood of the *névé* the broken masses tend to a prismatic shape, called séracs, from

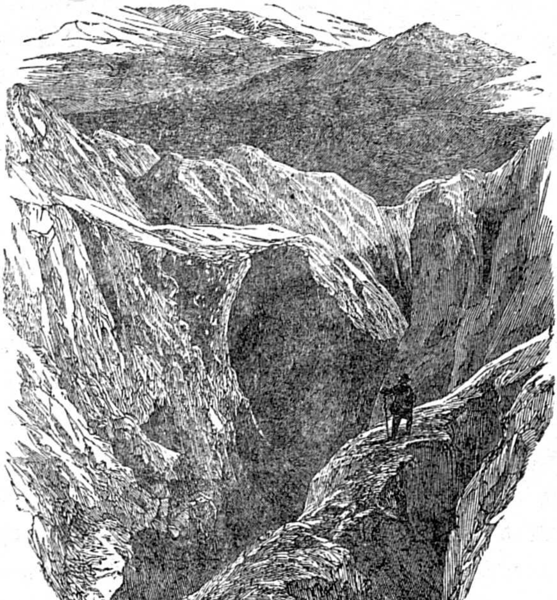
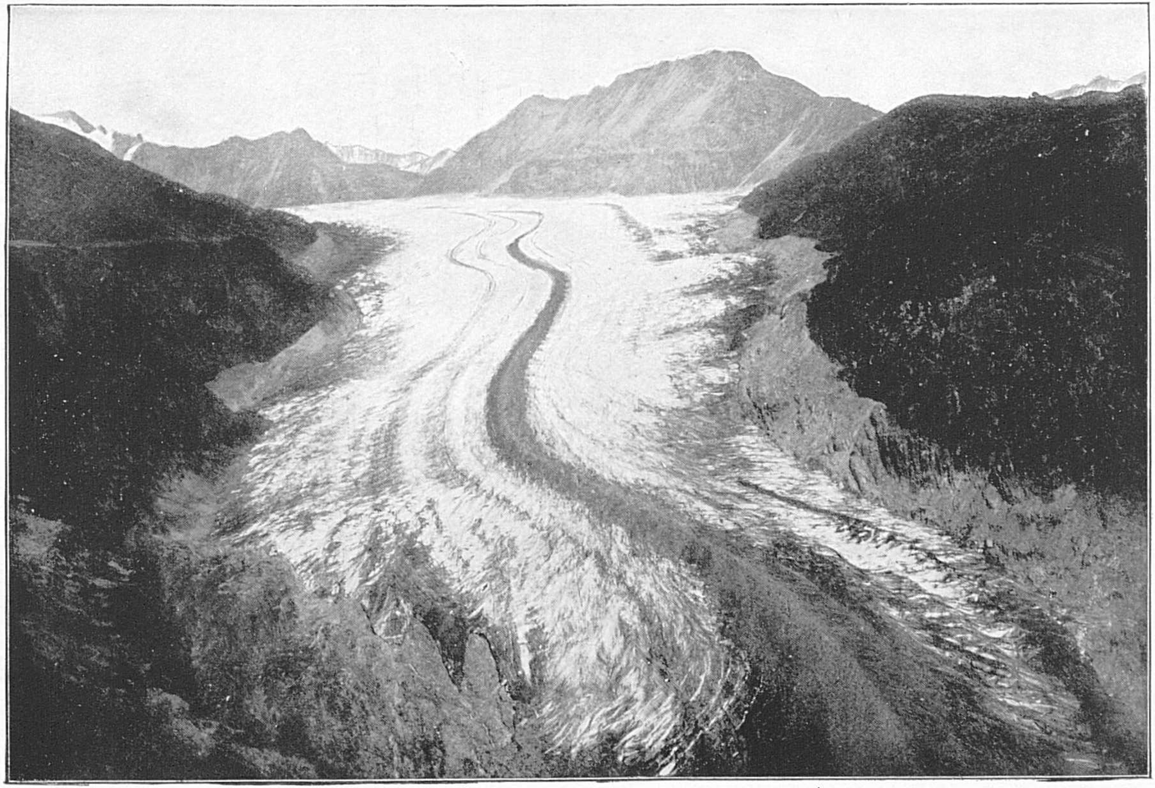


FIG. 8.—CREVASSES ON A GLACIER.

the curd in a particular kind of cheese, though the name is often extended to the other forms. Lower down these become more irregular wedges or pinnacles, but in any case the ice-fall is a serious, sometimes an insuperable, obstacle to any one attempting to travel up a glacier (Fig. 8).

Glaciers in the Alps, as in other parts of the world, are agents of denudation and of transport. To what extent they effect the former is a matter of dispute, which can be more conveniently discussed in another chapter. But on the latter there is a nearer approach to agreement. Fragments, detached from neighbouring peaks and cliffs, come tumbling down till they rest upon the surface of the ice. The great majority of them accumulate near the edge, thus forming a stony selvedge to the glacier, the materials of which range from mere grit to blocks often many cubic feet in volume. That is called a moraine, and such a one is distinguished by the epithet, lateral. One will be present on either side of every glacier which passes between exposed crags. But at the junction of two ice-streams from separate mountain valleys, the right-hand moraine of the one is fused with the left-hand moraine of the other, so as to form a single mound of broken rock, which at a distance has some resemblance, though, of course, less regular in outline, to a railway embankment. This is called a medial moraine, and the number of these will obviously be one less than that of the combining ice-streams. These medial moraines, however, do not wholly consist of broken rock. The latter screens the underlying ice from the heat of the sun, and thus prevents it from melting so rapidly as that on either side. Thus the mound of stones rests upon a second, though a flatter mound of ice, and the loose material may be in anything but stable equilibrium, as the unwary walker sometimes finds to his cost. The moraine retains this mound-like outline so long as the glacier passes over an even bed, but if that suddenly steepens or is interrupted by rocky steps, the ice is rent by



15. MORAINES OF GROSS ALETSCH GLACIER.
(From a photograph by Mrs. Aubrey Le Blond.)

To face p. 140.

crevasses, which swallow up part of the material and disperse the rest over its surface. Some of this, as we shall presently see, finds its way to the bottom of the glacier, but not a little of it returns to the light of day, some distance below the ice-fall, though it is now more widely scattered over the surface of the glacier. So the broken rock travels downwards, till at last it is dropped at the end of the glacier, and if that be stationary, forms there another mound, called a terminal moraine. This commonly is more or less crescent-shaped, because the ice naturally assumes that outline, and such a one may often be recognised in an Alpine valley, indicating the former presence of a glacier. Not seldom, however, three or four terminal moraines may be seen within a furlong or two of that which is still being formed, as, for instance, between the hotel at Gletsch and the end of the Rhone Glacier. Thus terminal moraines are records both of the former presence and of pauses in the retreat of a glacier, and, as a rule, they become larger, though sometimes less definite in shape, as their distance increases from the present end of the ice-stream. Fine examples of old terminal moraines may be seen in the Val Roseg, near Pontresina, and other Alpine valleys too numerous to mention ; but the most remarkable are those left on the lowlands of Piedmont by the ancient Dora Baltea Glacier. Here, as in the neighbourhood of Ivrea, a crescentic range, almost a horseshoe in plan, of flat-topped hills rises to a height of perhaps a thousand feet above the plain. These indicate that the ancient glacier[1] must have brought

[1] The ancient glacier must have been not much less than seventy-five miles in length.

down an enormous quantity of débris, and have halted in one position for an unusually long time. The Dora Baltea moraine, however, though the most remarkable,[1] is by no means a solitary instance. Large terminal moraines rise from the Italian lowland in advance of each of the great Alpine valleys. On the northern side also the glaciers extended far beyond the mountains, that of the Rhone, as we shall presently see, resting on the flanks of the Jura and reaching to the neighbourhood of Lyons. In a similar way the lateral moraines may form ridges, like railway embankments, on the side of a valley from which the ice has retreated, but conspicuous instances of these are not so common, probably because a slope is less favourable than level ground for the accumulation of material, which also may be spread more uniformly, because the surface of the ice sinks more slowly than its end retreats.

Very fine grit absorbs heat from the sun, and by radiation melts the ice in contact with it. Thus the surface of a glacier is often pockmarked with small holes, at the bottom of which is a grain or two of rock; or, where dusty material covers a larger area, it forms a little basin, partly filled with water, at the bottom of which it lies like a dark sediment. But as the coating of débris thickens, its effect becomes protective instead of corrosive; thus cones replace the hollows, and ribs of ice, as already described, underlie the moraines. Of this process the larger blocks, if separated from others, often afford striking examples,

[1] It is said (J. Geikie, "Great Ice Age," p. 529) to have a frontage of at least fifty miles and to rise at one place to very nearly 2,000 feet. I think, however, this must mean above sea-level.

From a photo by] [*Dr. Tempest Anderson.*

16. A GLACIER TABLE.

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especially when they are tabular in form. Such a one protects the ice beneath, so that it becomes a pedestal as the surface of the glacier sinks. The thickness of this, however, diminishes as its height increases; for the stony parasol cannot be a complete protection, and the surrounding air is often warm enough to melt the sides. So these glacier tables may be sometimes not less than two or three yards in length and breadth, and they often incline slightly to the south, as they receive most heat from that quarter. At last the stem no longer suffices to support the cap-stone, which slips down to the surface of the glacier and recommences the process. A large block, apparently, tends to become separate from its smaller companions on the ice, probably because it is in a less stable position than they, and at last is stranded in solitude, perhaps far beyond the present limits of the glacier. Examples of such erratics or "perched blocks" may be found in every part of the Alps.[1] For examples we need not go beyond a single glacier system, that of the Rhone. Three great boulders of a peculiar kind of serpentine lie on the bed of the Saas-thal, slightly above the Mattmark See and not far from the end of the Schwarzberg Glacier, on which the largest, according to testimony cited by De Charpentier, was actually resting about 160 years ago.[2] According to Mr. E. Whymper, it measures in feet $86\frac{1}{4} \times 72\frac{2}{3}$ and over 65 high.[3] In the

[1] They occur, of course, in other glaciated regions, including our own country.

[2] "Essai sur les Glaciers" (1841), p. 252.

[3] Letter dated October 21, 1900. De Charpentier (*ut supra*, p. 41) gives $72\frac{1}{2} \times 60\frac{3}{4} \times 69$ (English measures). My own measurements, rather rough, were smaller.

neighbourhood of Monthey, in the valley of the Rhone, is another remarkable instance, which long ago attracted the attention of geologists. There hundreds, perhaps thousands, of erratics were lying on the slope of Jurassic rock at the entrance of the Val d'Illiez. They are crystalline rock, for the most part protogine, from the eastern part of the Mont Blanc range. Some are of great size—the largest of them, called Pierre des Marmettes, according to De Charpentier, measures 63 feet long, 32 broad, and 30 high, so its volume is about 60,480 cubic feet.[1] Some others vary from 20,000 to 50,000 cubic feet.[2] These evidently formed part of a scattered lateral moraine of the Rhone Glacier.[3] Rocks of the same kind lie upon the slopes of the Jura, indicating a terminal moraine of the same glacier. One of these has long been famous. The *Pierre à bot*—so called from a fancied resemblance to a squatting toad—lies in a wood near Neuchâtel, rather more than a mile in a direct line from the lake, and some 400 feet above it. Its volume is asserted to be 40,000 cubic feet.[4]

But we must leave for the present the ancient

[1] In English feet the length would be about 67, the breadth 34, and the height 32 feet.

[2] "Essai sur les Glaciers," p. 126. The measurements are probably in French feet.

[3] The number of these has been greatly diminished since first I examined them in 1859. My note when last I saw them (in 1907) runs thus: "I think they have broken up all the larger ones (excluding one or two of the very biggest), especially those of protogine."

[4] De Charpentier, *loc. cit.* The sketch from the pencil of Professor J. D. Forbes represents it lying on nearly level ground, instead of an irregular and rather sloping surface. It can hardly have travelled less than seventy miles. Murray's Guide gives a more moderate volume, with a length of 62 feet and a breadth of 48 feet.

From a photo by] [*Mr. J. J. Lister, F.R.S.*

17. PIERRE-À-BOT, NEAR NEUCHÂTEL.

To face p. 144.

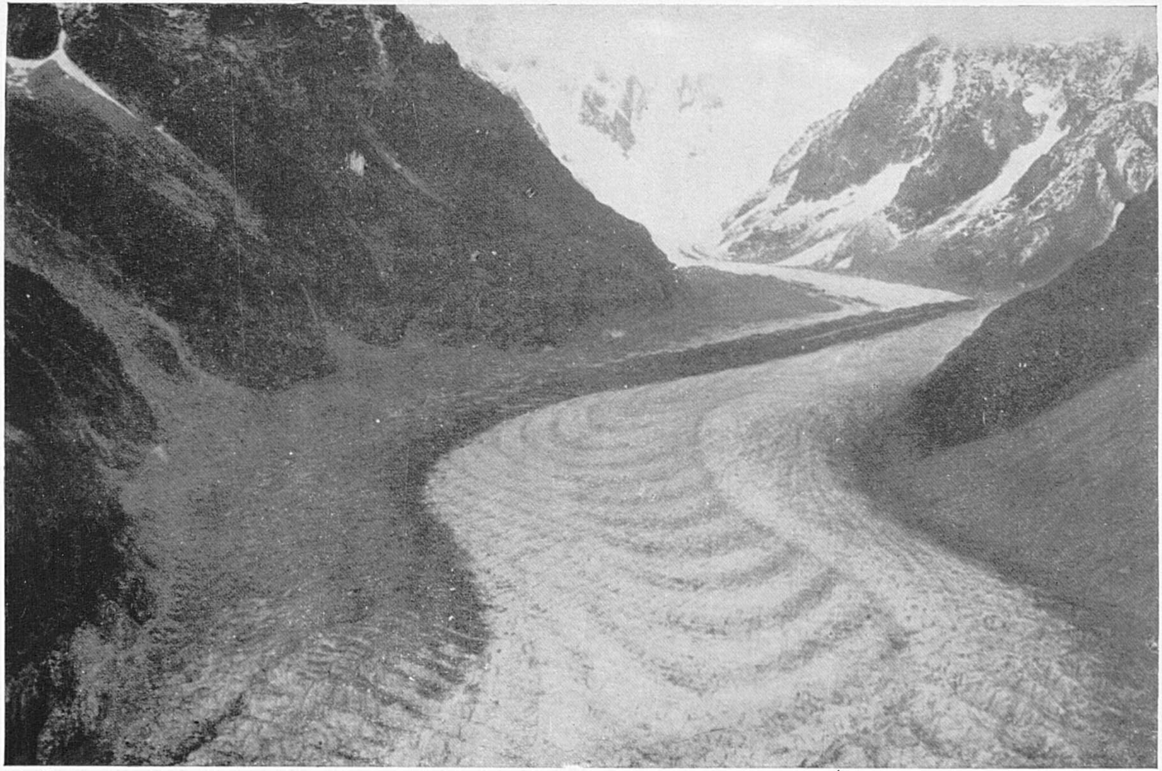
moraines of the Alpine glaciers in order to notice other phenomena in more immediate connection with the existing ice-streams. At the foot of an icefall, as already said, a moraine has often largely, sometimes almost wholly, disappeared, having been engulfed in the crevasses. Presently, however, it can be seen slowly emerging, as if the indigestible material were disgorged from the maw of the monster. This is no doubt partly due to the melting of the surface, but the reappearance is sometimes too rapid for this explanation to be wholly satisfactory. It suggests some upward movement in the ice, like that in water after plunging over a fall. Theoretical considerations for a time made this explanation doubtful,[1] but they have been answered by Professor Sollas's remarkable experiments with *poissiers*, or models of glaciers in cobbler's wax. These demonstrate that in a plastic material, and such is ice, whatever may be the physical explanation, movements of this kind really exist. Hence much of the swallowed-up débris returns to the surface, but some of that which has fallen into the deeper crevasses, either remains embedded in the glacier or finds its way to the bottom. Therefore material is transported either on, or in, or beneath a glacier. In the last case it is augmented in another way. The ice rubs the surface of the underlying rock and rasps it with the embedded grit and stones. It is accordingly abraded, worn, smoothed and striated. To what extent this is done is a question which must presently receive attention, but that the effect is considerable is generally admitted. The joint result is the so-called ground moraine,

[1] See the Author, "Ice Work," p. 184.

which is defined as "all the drift deposited beneath the advancing ice, and all deposited from the base of the ice during its dissolution."[1] The stone "scrapers" also are similarly worn, and as the ice grasps those rather irregular in shape more firmly in some positions than in others, they are better smoothed and striated in certain parts, and thus can be readily recognised.

The surface of some glaciers—for example, part of the Mer de Glace or of the Arolla Glacier—when they are looked at from a little distance, exhibit a succession of fairly broad dirty-looking bands, rather similar in outline, and forming a series of curves which point downwards. These are called dirt-bands, and indicate the presence of more than an average amount of mud and grit. Their more or less hyperbolic form is no doubt due to the more rapid movement of the middle part of the glacier, but it is not easy to explain the rhythmic alternation of dirty and clear ice. Professor J. D. Forbes, the first, we believe, to call attention to this phenomenon, explained it by the alternation of bands of solid and more porous ice (the veined structure), the latter of which afforded a better lodgment to detritus. Professor Tyndall, however, maintained that this explanation confounded cause and effect, and that the occurrence of an icefall is a necessary antecedent to the phenomenon. By means of this the glacier is transversely fractured, and after the crevasses have been closed up, some distance from the foot of the cascade, ridges remain, with hollows between them, in which the dirt gradually accumulates. These ridges are subsequently "toned down" to gentle protuber-

[1] Chamberlin and Salisbury, "Geology," vol. i. p. 287.



From a photo by] [*Dr. Tempest Anderson.*

18. DIRT-BANDS ON A GLACIER, MER DE GLACE.

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ances, which sweep across the glacier, and the dirt collects upon the slopes and at the bases of these protuberances. On the whole, this explanation seems to be the more probable.

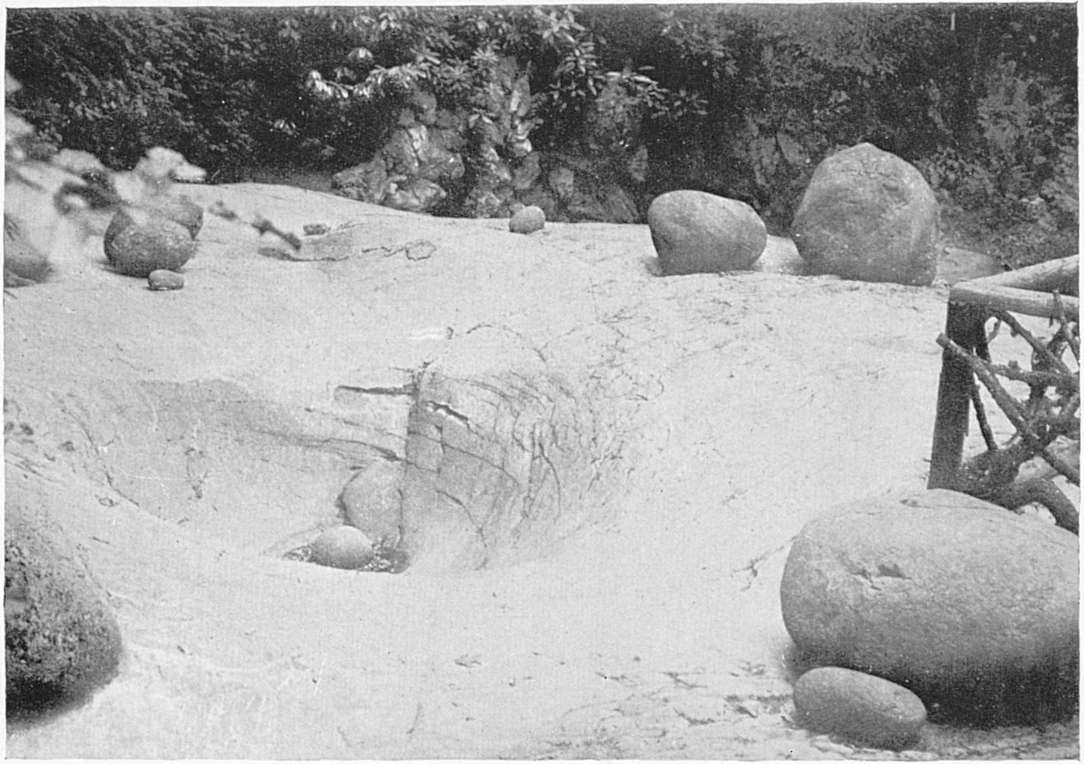
When the ice has become sufficiently solid to prevent any appreciable percolation of water, that from the melting surface gradually forms runlets and rivulets, which unite into a miniature super-glacial river system. Its trunk stream may become a few feet in width and inches in depth, but its course is arrested if a crevasse opens across its path. Plunging downwards, it drills its way to the bottom of the glacier, enlarges the shaft, and works out for itself a subglacial channel. But as the glacier, in moving on, obtains relief from the strain, the chasm is closed. The shaft, however, remains, moving downwards and engulfing the stream. This is called a *moulin*. But after a time another rift may open out near the old position, cutting off the stream and forming a new waterfall. I have occasionally seen two or three dry shafts travelling in advance of one which is still in activity. Stones not seldom fall down the moulin, and are bounced about by the cascade, forming potholes similar to those produced by a torrent. These are called giant's kettles (*marmites de géant*). The most remarkable instances which, so far as I know, can be seen in the Alps,[1] are at the so-called Glacier Garden, near the famous Lion monument, at Lucerne. "They are about nine in number, irregularly dispersed over an area of perhaps half an acre, the biggest being

[1] They may be found in the mountainous districts of our own islands, and I have seen some fine examples in Norway, especially in the Otteraa valley, near Christiansand.

about 26 feet wide and 28 feet deep. The bed of more than one has assumed a spiral form ; thus showing that the gyratory movement of the plunging water of the cascade was constant in direction. These 'kettles,' when first discovered, were filled with débris, and still contained the large rounded boulders, by which they had been mainly excavated. The surface of the sandstone (molasse) between the most conspicuous examples is smoothed and striated, but a shelving craglet of rock, which in one place interrupts the uniformity of this surface, indicates that the action of the ice has not been continued long enough to obliterate all previous inequalities. The débris must have been deposited after the moulins had ceased to act, and in all probability during the retreat of the glacier."[1]

It will be more convenient to describe the forms produced by the abrasive action of these gigantic ice-rasps when we consider what part they have played in the shaping of the Alpine peaks and the excavation of their valleys. So it will suffice for the present to say that they tend to wear down ridges and remove asperities, that they give to the rocks over which they have passed a peculiar rounding which makes them like the backs of sheep, whence comes their ordinary name, *roches moutonnées*, or, to use Ruskin's more poetic simile, their billowy hummocks are "like the backs of plunging dolphins." These surfaces are smoothed and sometimes even polished. The extent of the latter depends partly on the nature of the rock, limestones and other compact rocks like serpentines taking a better polish than granites,

[1] The Author, "Ice Work" (1896), p. 34.



From a photo by] [*Dr. Tempest Anderson.*

19. THE GLACIER GARDEN, LUCERNE.

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gneisses, or schists; but as Nature's "putty powder" is mixed with some little grit, the surface is always more or less scratched. As a rule it is in the best condition in places from which the ice has but recently disappeared, and many excellent specimens have been exposed by the marked retreat of the Alpine glaciers, which began about the year 1863.

As already stated, the Alpine glaciers were once very much larger than now. The snow-line was much lower; they occupied many valleys from which they have now entirely disappeared; they rose high above their beds, and extended far beyond their present limits. That subject is fully discussed by Professors Penck and Brückner in their book on the Ice Age in the Alps,[1] a work the value of which, though I cannot accept some of the conclusions, I gladly acknowledge. They maintain that the Glacial Age included four distinct epochs of cold, during each of which the temperature was considerably lower than it is at the present time, and that, in the intervals between them, it differed little from, perhaps was sometimes rather higher than, what it now is. These are the so-called Interglacial Ages. For convenience of reference, Penck and Brückner have given names to each of these glacial ages, calling the first the Günz, the second the Mindel, the third the Riss, and the fourth the Würm; the temperature in the third and fourth being rather lower than in the first and second, and the third slightly the coldest of all. They place the snow-line, when the temperature was lowest, about 3,900 to 4,300 feet below its present level, while they think it was sometimes a little higher in the Inter-

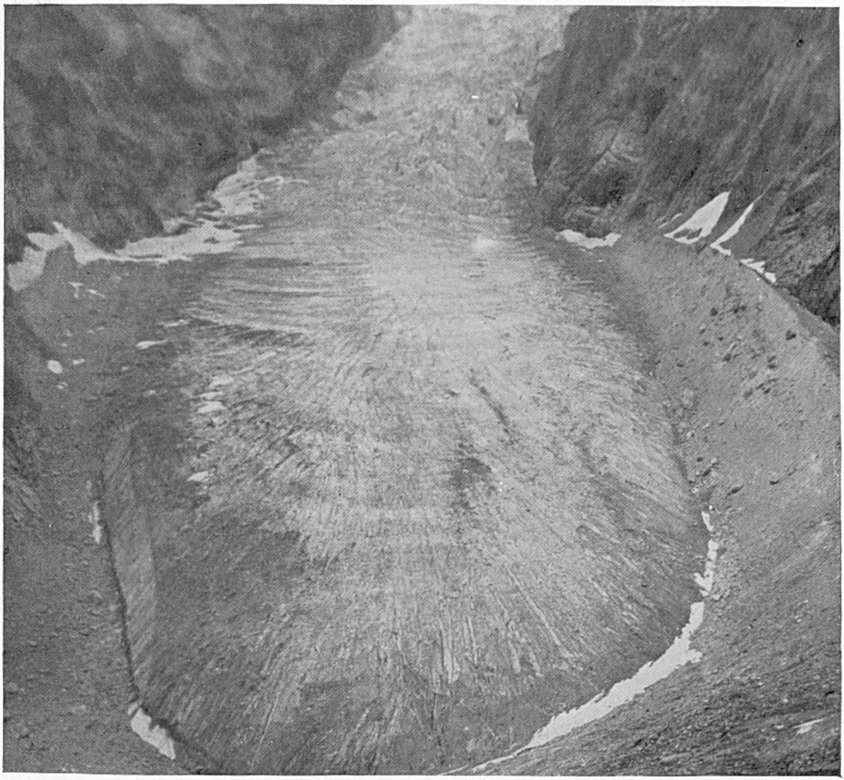
[1] "Die Alpen im Eiszeitalter" (1909).

glacial Ages.[1] But, of course, the transition from the one extreme to the other would be gradual, so that the climate during the greater part of the Glacial Age would be colder, and sometimes much colder, than at the present day. The length of these ages also was not the same. Penck and Brückner maintain the Riss ice age to have been longer than the Würm, but the Mindel nearly equal to it, and even the Günz cannot have been short. The Mindel-Riss Interglacial was much longer than the Riss-Würm, and either than the post-glacial time. If we take the last as a unit, the second would be represented by 3 and the first by 12.

In these periods denudation was active. To the Günz-Mindel belong the older *deckenschotter*, or plateau gravels—coarse deposits of rounded pebbles, which, however, sometimes contain large boulders, such could hardly be transported without being to some extent buoyed up by ice; to the Mindel-Riss belong the newer *deckenschotter*, gravels less tumultuous in aspect and rather more immediately connected with the present river valleys; and to the Riss-Würm the older, well bedded, well rounded gravels in these valleys, but at some height above the water-level, *i.e.*, the older "terrace gravels," the newer belonging to post-glacial times. The authors have constructed a curve of temperature, according to which the latter was lower than now for rather less than halt of the Ice Age.[2] A difference in the snow-line of 4,000 feet would correspond with a general drop in

[1] The exact figures are 1,200 to 1,300 metres, vol. ii. p. 1168.

[2] The figures work out to 0·4715 for the colder time and 0·5285 for the warmer, or nearly as 47 to 53.



From a photo by] [*Dr. Tempest Anderson.*

20. END OF PRÉ DE BAR GLACIER.

To face p. 150.

temperature amounting to 12° or perhaps 13°.[1] This would very largely increase the area of the snowfields, would fill with tributary glaciers hundreds of lateral valleys which now wear a white mantle only in the winter season, and would consequently add greatly to the volume of the main ice-streams; and as it would bring down the mean temperature of the lowlands to from 34° to 37° in Switzerland and to about 40° on the Italian side, it might so greatly reduce the waste of the ice as to allow of that great extension which has been already described.

[1] By a different method of approximation I estimated 15° as the least drop, but with so much larger an area of snow and ice the fall of the thermometer might be more rapid than now (viz., about 1° per 320 feet). If it were 1° for 275 feet, a lowering of 4,000 feet might mean a drop in temperature of between 14° and 15°. (See "Ice Work," pt. iii. ch. i.)

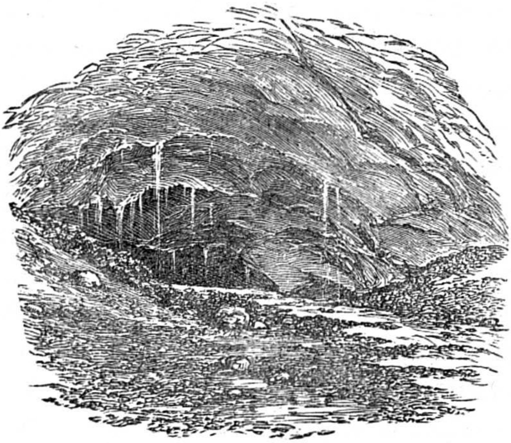


FIG. 9.—THE END OF A GLACIER.

CHAPTER VII

THE MAKING OF THE PEAKS AND VALLEYS OF THE ALPS

THE Alps have been carved, like other mountains, out of more extensive and continuous masses of rock. In this process water has been the main agent, chiefly as rain and rivers, but to some extent in its solid form. Heat and frost have co-operated, but perhaps more in shaping the peaks than in excavating the valleys. Something also must have been due to inequality in strength and diversity in arrangement of the materials. The rivers have not cut their downward way through a continuous system of uniformly bedded rock, but through masses twisted, broken, variable in thickness, and resting on foundations irregular in surface and in outline. These also, during the process of sculpture, were not at rest, but in motion; often continuously, though at different rates, as has been described in an earlier chapter. It is also probable that sometimes a movement in one direction was succeeded by another, though perhaps comparatively slight, in the contrary. Thus the Alps afford a very complicated problem, and the solution offered for one part may require considerable modification before it can be applied to another.

The physical structure of the chain, as has already been pointed out, alters considerably as its course is traced from end to end, and we shall find in this fact the more convenient method of discussing its valley systems and their significance. As a preliminary it may be well to remind the ordinary reader of the primary facts of valley making. Suppose an area of land, in outline an elongated ellipse, in shape a low dome, to be rising slowly above the sea. No sooner has it appeared than rain, not to mention other meteoric agencies, sets to work upon it. The water in running off furrows the surface. At first it follows the line of quickest descent, and traces a number of channels radiating outwards from the centre of the ellipse, or rather from its central axis. But soon another set of furrows will be begun. The areas between these channels will have to be drained, and the water as it runs off them will originate a second set of valleys, sometimes almost at right angles to the former, which will gradually work their way backwards. But the upper part of the dome would probably be planed away by the sea before it rose above the waves, so the portion first exposed to view would consist of concentric rings of harder and softer rocks. These would determine the position of the longitudinal valleys, which, when once begun, would be prevented by the harder masses on either side from straying beyond the band of softer material. Again, since streams flowing in opposite directions, whether radially or longitudinally, may differ in velocity, and thus in erosive power, cases of trespass may occur where the head of one valley in a more rapid retreat cuts back through the watershed into the territory of another, and even "captures" some of its tributary streams.

Thus the central axis, or main watershed, of a mountain chain should indicate roughly the part of the region which first rose above the ocean ; the valleys at right angles to it corresponding with the former of the two groups, which have just been mentioned, and those parallel to it with the latter. Geologists of late have taken to call the one "consequent" and the other "subsequent" valleys. Formerly they were named respectively "dip valleys" and "strike valleys," because the one follows the "dip," the other the "strike" of the strata; and though the rocks are not always stratified, I prefer them as expressions of simple facts rather than of complicated ideas, because even the crystalline rocks in a mountain district commonly have assumed a structure resembling bedding, and I should use them here were it not that folds are often so frequent that though the mass, as a whole, may be said to plunge in one direction, that can only be learnt from the map, and may apparently be contradicted by what is seen in passing over the ground. So as this chapter deals with the rocks on a large scale, I shall prefer to call the former set—those initiated by the general dip of the rocks—transverse valleys, and the latter—those initiated by the strike—longitudinal valleys.

Subdivisions, however, will sometimes be formed in the troughs of longitudinal valleys, and reversals of drainage may occasionally be possible. A stream, after descending a transverse valley, may be diverted along a longitudinal one into the transverse valley of a neighbouring system, and thus leave the lower part of its own comparatively waterless. The result will be that as the portion of the channel still occupied by the active stream is deepened, the remainder of it is gradually converted into an upland trough cutting through the hills. In this, after a time, another stream will be formed, which will make a new and a more restricted furrow in the old channel. These facts then, together with the complications in rock structure to which I have already called attention, must be borne in mind when we are attempting to ascertain the history of the river systems and consequent sculpture of the Alps.

For our present purpose we may divide this chain into three sections: the western (or, more strictly, south-western), the central, and the eastern; each having its special complications. These, in the first group, are due to the presence of a great fold, or rather group of folds, parallel, though very roughly, with the more eastern range, which is the watershed of the chain. Its southern end is limited by the Mediterranean. For its northern—really its north-eastern—boundary, we may take a line drawn up the Rhone valley from the Lake of Geneva and prolonged nearly in the same direction to the Italian plain. The eastern limit of the central region has a more zigzag course, for it corresponds at first with the crest of the range, dividing the upper waters of the Rhine and the Inn, then turns eastwards to separate the drainage of the latter river from that of the Po, and lastly runs almost parallel with its former course, along an offshoot, which goes to the Italian plain between the Val Tellina and the Val Camonica. To the east of this central region comes the third one, which has a simpler structure than either of the others, and in which the main or longitudinal valleys take a more or less eastward course. But in all three regions any insulated patch of hard rock generally becomes the centre of a little drainage system of its own, the streams of which are, however, before long compelled to become tributaries to one of the great rivers of the chain.

Starting from the Mediterranean, beyond the complication produced by the inosculation of the Maritime Alps with the Apennines, we find that the small crystalline *massif* of the Punta dell'Argentera, which is insulated from the main Cottian *massif* by a band of sedimentaries, sends a little water from its northern extremity down the Ubaye to the Rhone, while all the drainage from its long north-eastern face flows to the Po, and that from the corresponding south-western one to the Var. Farther north the river-system of the Cottian Alps is simple—to the Po on one side; to the Rhone by way of the Durance on the other. But to the west of the last-named river complications are introduced by the rise of the compound folds of the Dauphiné Alps. The watershed of the chief of these, that of which Les Ecrins is the culminating peak, lies well on the eastern side, with the result that comparatively little water finds its way to the Durance; most of it being collected by the Romanche and thus reaching the Rhone along the channel of the Isère. In so doing it cuts completely through the outlying crystalline folds—those of the Grandes Rousses and the Belledonne—showing that these must have been rather later in date and subordinate in importance to the above-named *massif*, but the latter of the two, though now the less elevated, seems to be connected, towards the north, with a larger area of crystalline rock and able to compel the Romanche to cross it by an oblique instead of a directly transverse course.

Yet farther north the watershed of the Cottians, till we approach the axis of Mont Blanc, is prolonged towards that point of the compass. Both the Arc and the Isère run off its western slopes, alternating between transverse and longitudinal courses among the softer rocks, and cutting, in the former of these, completely through the northward prolongation of the Grandes Rousses and Belledonne folds, and proving the folds subordinate to the Cottian range as well as to the *massif* of Les Ecrins. But the towering mass of Mont Blanc introduces a complication. As already noticed farther south, the folds parallel with its north-western face are unable to modify the drainage system, and the water from that face is carried off to the Rhone by transverse valleys—from the more southern part by the Arve, from the other one by the shorter course of the Trient. Some of that from the south-eastern face takes a course parallel to the latter river along one arm of the Dranse, but the remainder, collected in a narrow trough of sedimentary rock, discharges itself into the long valley of the Dora Baltea and thus finds its way to the Po. Here, then, a river has sawn its backward way through the proper watershed of the chain, a singular fact which, I think, may be due to the exceptional elevation of the Mont Blanc *massif* in such very close proximity to the principal watershed, which also seems to have been rather lower than usual in this part, as indeed it is for some little distance to the south. Thus the two ranges may have been welded into one mass so completely that there may have been alterations of the original drainage system, and the water from the eastern side of this mass, instead of following the example of the Arc and the Isère, contrived to force its way into the pre-existing valley of the Dora Baltea.[1]

Across the transverse valley, followed by the Rhone from Martigny to the Lake of Geneva, we pass into the central district, where the structure reverts to the type generally characteristic of the other one. A long and slightly bent trough of softer rocks, mostly Mesozoic in age, running parallel with the crest of the Pennine and Lepontine Alps, separates the crystalline mass of the watershed from the long range of the Oberland. This trough is continued over the Furka Pass to form the short upper reach of the Reuss, and then over the Oberalp Pass to determine the course of the Vorder Rhein, as far as Chur, when the united waters of the main river follow a transverse valley down to the Lake of Constance. Thus the northern wall of this trough, some 135 miles in length between the outlets of the Rhone and the Rhine, is breached only at one place, where the Reuss, after a short course within the trough, escapes through a narrow glen—really a transverse valley—down to the Lake of Lucerne.

The river system of the eastern district is unusually perplexing in its western parts, but afterwards, though not without some difficulties, it becomes more simple. The former includes the region, already described,[2] where the great east and west foldings of the Alpine chain are obviously affected by some broad flexures trending from N.N.E. to S.S.W.; though the latter

[1] *Alpine Journal*, vol. xiv. p. 117.

[2] See p. 74.

do not conspicuously affect the marginal outlines of the chain. They seem, however, to have produced certain anomalies in the course of the rivers. For some distance on each side of the Brenner Pass the hydrographic structure is simple enough—a central crystalline range forming the watershed, flanked, north and south, by a range of sedimentary rocks, through which at rare intervals the water finds an outlet after being collected in the longitudinal troughs. There is no conspicuous uplifting of the northern zone, no squeezing up of its crystalline foundations, as in the Bernese Oberland, no corresponding upheaval of the pebble beds and sandstones, which were formed by detritus from the chain that existed in Oligocene and Miocene ages. I believe, in fact, that the general aspect of the latter is better retained in this region than in any other part of the Alps. But with the valley of the Upper Inn a marked, and in some respects unique, change takes place in the hydrographic system of the Alps.[1] That river rises in the southern range and cuts through the central one, thus altering the position of the watershed of Europe. Not only so, but in its earlier days it began its course, as will presently be explained, considerably to the south of the Maloja Pass,[2] and thus made, in combination with the feeders of the Oberhalbstein Rhine, a very curious flexure in that watershed. Nor is that all: for the head-waters of the Etsch or Adige, which carries southward no small amount of the drainage

[1] The water from the southern side of the Mont Blanc range, as described above, also cuts through the watershed, but in the present case the explanation there suggested does not seem to be applicable.

[2] Probably between five and six miles.

from the crystalline axis of the Western Tyrol, have an even more perplexing relation to the valley of the Upper Inn. At the well-known defile of the Finstermünz that river has descended to a level of about 3,700 feet above the sea—a drop of some 2,300 feet. Here it can be reached from the head of the Etsch valley by a steep descent from a pass called the Reschen Scheideck. But this pass (4,898 feet) is only about 1,200 feet above the Inn, and instead of going over a well-marked crest it lies on a long and comparatively level trough—the Malser Heide—between mountains some two or three thousand feet above it. From its highest point the road declines gradually to the village of Nauders (4,468 feet), and then drops rapidly down to the gorge of the Inn. So the head of the Etsch valley must have been truncated, as will be more fully described hereafter, by a tributary to the Inn; but, as the latter river is now more than fifty miles away from its source, we cannot but be surprised to find its channel so near to an important feeder of a totally different drainage system. Here, however, the Inn is running near one edge of a broad synclinal—part of the system of N.N.E.-S.S.W. folds which has been already mentioned. This certainly seems to have helped in determining its course, so that perhaps some parallel but subordinate anticline has been just potent enough to restrict this part of the river to a rather narrow channel. I offer this explanation with diffidence, fully realising the difficulties of the problem; the more so, because, though I have been as far as Nauders, I have not actually crossed the Reschen Scheideck from the Finstermünz to Meran.

When the Inn has reached Landeck it bends sharply to the right, and changes from an oblique to a normal course. It then runs along a rather broad and longitudinal valley between the central crystalline and the northern sedimentary ranges, in which it continues for at least seventy-five miles and then cuts, in the main transversely, across the latter range; following the example of the Rhone, Reuss, and Rhine. South of the chief watershed the Etsch, already mentioned, and the lower part of the Eisack, take courses which are on the whole oblique, but the upper part of the latter is really a longitudinal valley, for the Pusterthal, as it is called, lies between the central crystalline range and the southern one, well known as the "Dolomite" Alps. But after the confluence of the two rivers at Botzen, the Etsch, or Adige, though its course is nearly S.S.W., really occupies a longitudinal valley, because it is following the eastern edge of that minor fold which has been already mentioned. The head of the Eisack, like that of the Etsch, exhibits peculiarities which will presently be noticed, and the longitude of Kufstein, speaking in general terms, corresponds with a marked change in the direction of the principal drainage channels of the Eastern Alps.

East of the Inn, its tributary the Salza, and the Enns, are the last rivers to take a northward course from the corresponding side of the central (crystalline) axis, but on the other one no stream of importance, after the Adige, reaches the Adriatic to the south of Venice. From the remainder of the chain the great rivers follow a more or less easterly course. In this direction the crystalline axis terminates in a wide fork; one prong—the longer and northern—extending almost to the Neusiedler Lake; the other stopping short near Marburg. Between the two, rocks of Devonian age, overlapped by later Tertiary, make their appearance; while south of a line joining that town to Udine, the south-south-east trend of the strata, which is characteristic of the Dinaric Alps, becomes very conspicuous. Beyond the region of the Enns no stream of importance proceeds from the northern part of the central axis towards that point of the compass. The first great river, the Mur, after taking for a time a course along, rather than by the side of, the northern fork,[1] turns sharply southwards, follows a transverse path to Gratz, and ultimately joins the Drave. The latter river, to the head of which we must presently refer, starts from the southern slope of the central axis, some distance west of the Mur, and proceeds by a course which, on the whole, is probably radial rather than longitudinal, to Marburg, where it begins to get free from the restriction of mountains. The Save, though an important river, and following a generally similar course, takes its rise in the southern zone, though near to the northern margin; and of the streams going direct to the Adriatic, east of the Adige, the Piave alone[2] nearly succeeds in cutting back into the longitudinal valley of the Pusterthal.

Such are the relations, so far as they can be briefly described, of the Alpine valleys to the structural

[1] Of course these valleys are really transverse; because, as the elliptical area is very elongated, they are following the direction of radii.

[2] Strictly speaking its tributary, the Boita.

features of the rocks from which they have been carved. We have now to discuss the agents by which they, with the mountain ridges and peaks, have been sculptured. This investigation will lead us into controversial questions, but for the moment we may assume, as has already been tacitly done, that the above-named features have been shaped, at least to a large extent, by heat and frost, rain and rivers; though the late Professor Tyndall maintained that glaciers were far the most important agents in the excavation of Alpine valleys. These are his words: "That such an agent was competent to plough out the Alpine valleys, cannot, I think, be doubted; while the fact that, during the ages which have elapsed since its disappearance, the ordinary denuding action of the atmosphere has been unable, in most cases, to obliterate even the superficial traces of the glaciers, suggests the incompetence of that action to produce the same effect. That glaciers have been the real excavators seems to me far more probable than the supposition that they merely filled valleys, which were previously formed by what would undoubtedly be a weaker agent. Or shall we conclude that they have been the excavators which have furrowed the uplifted land with the valleys which now intersect it? I do not hesitate to accept the latter view."[1] As, however, this view was at once repudiated, even by those who credited glaciers with considerable erosive power, and seems to ignore the existence of peaks and valleys in regions altogether below the snow-line, we may be content to dismiss it as a result of a use of the imagination which was the reverse

[1] *Phil. Mag.*, 1862, p. 379.

of scientific, and will presently consider those which, while attributing considerable potency to ice, are much less exacting.

Peaks, ridges, and valley-slopes are but the remnants of semi-cylindrical masses of rock, often crumpled by minor folds, from which they have been carved in the lapse of ages (Fig. 10). To avoid complications, let us carry back our thoughts to a time when the mean temperature of Central Europe was still too high to permit the formation of glaciers. If it were only 12° F. higher than now, no glaciers of the slighest importance could exist in the Alps, and permanent snowbeds would vanish from all summits but those exceeding 12,000 feet in height. At the same time, snow would fall heavily in winter and linger late in the spring from about 4,500 feet upwards. Thus all streams that had their birth among the highest peaks would flow full and strong for several months in the year, and would not run dry even in summer, as happens now to many of those in the Apennines. The denuding effect, however, of running water would be less than its present amount in the higher valleys and greater in the lower. A snowbed—whatever may be the case with a glacier—protects the rock beneath it, and the water melted from it "dribbles" rather than runs away, producing many streamlets rather than one strong stream. The former after a time collect—like brooklets on a British moor—but by no means speedily. There will then be little furrowing and no gorge-cutting in the higher mountain region. Here, I believe, denudation would be greatly quickened by the formation of a glacier, and in addition to this the lowering of temperature would increase the activity of destructive meteoric agencies, which, however, would always be considerable at such an elevation during a large part of the year. To whatever it may be due, the fact is certain that in the upper valleys a marked change in the slopes and contours is perceptible at a height varying from something like 800 to 1,200 feet above the present floor.[1] Above this we enter a region where, for a considerable distance, the mountain slopes become, as a rule, more gentle, the valleys wider, and (in

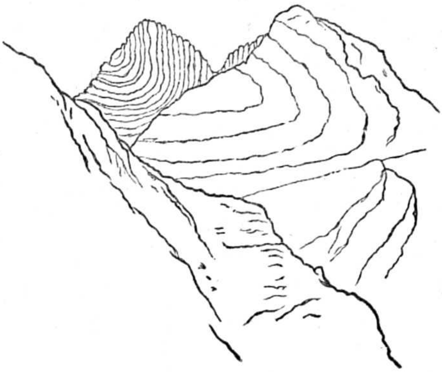


FIG. 10.—PEAKS CARVED FROM FOLDED ROCKS (LIMESTONE).

the absence of glaciers) shallower, but they are at the same time divided by more precipitous and sharper ridges, with jagged skylines. A change, the significance of which we shall presently consider, evidently took place in the processes of denudation, and to whatever this was due, we are justified in inferring that, if we imagine the lower trenches to

[1] It is impossible to make a precise statement. Many valuable facts bearing on this are given by Penck and Brückner (*ut supra*, vol. ii.).

be filled up, we can form a very rough idea of the aspect of the Alps at the end of a period when the mean temperature was considerably higher than now. Here it will be convenient to mention some other features of which any explanation must take account. Very commonly also the floor of an important lateral valley, at its junction with one of the main valleys, so far from being at the same level with that of the latter, terminates abruptly, perhaps 1,200 feet above it. I have noticed this in many, perhaps I may say most, of the great Alpine valleys, but think it is more marked in those connected with the central range. The valley of the Rhone above Bex affords frequent examples, the more striking occurring on its left bank—such as the mouth of the Val d'Hérens above Sion and the Val d'Anniviers above Sierre. Valleys of this type have received the appropriate name of Hanging Valleys. The structure is less conspicuous in the valley of the Dranse, as seen from Martigny, and in the Turtmannthal, while that of the Visp appears at first sight to be an exception. Here, however, we find that a well-marked break in the level exists at Stalden, close to the junction of the glens leading to Zermatt and to Saas.

With the latter a second set of hanging valleys is associated, such as that in which Saas Fee nestles, or, on the right bank, those leading respectively to the Trift Glacier, the Zwischbergen Pass, and the Antrona Pass. These upper hanging valleys are rather variable in section—being sometimes, as at Saas Fee, rather wide troughs, more or less flat-bottomed, or like the lower portion of a letter U in section; while the lower set—of which most of the larger transverse valleys of the central range are examples—keep, as a rule, to the V outline. To this fact we shall return.

In crossing one of the Alpine passes we observe the "divide" has one of two forms. In some cases it is a narrow ridge reached on either side by a fairly steep ascent; in others a trough running through the range, so level that occasionally it is no easy task to fix the position of the watershed. The former is common, though by no means invariable, among the glacier passes; but since in them the true form of the rock is often concealed by a thick snowbed, we will speak of those between about 6,000 and 8,000 feet, more or less. Here, while passes of the other type can be found, those which are "trench topped" are the commoner.[1] The Maloja Pass may serve as an example, for it is one of the most striking. "The valley of the Inn ascends, on the whole gradually, to Samaden, where the river is joined by a torrent which carries the drainage from the northern part of the Bernina group. But though this brings the greater volume of water, it occupies a glen which is, orographically, of secondary importance, and the main valley continues onwards in a south-westerly direction to the Maloja Pass. Samaden is about 5,600 feet above the sea; from it a rather steep but short ascent brings us to the level of the St. Moritzersee, the elevation of which is about 5,800 feet. We have now entered a broad and almost level valley, enclosed between mountains which rise on either side from 4,000 to 6,000 feet above it, the floor of which is occupied to a considerable extent by a group of

[1] I am speaking throughout of passes that cross a range, rather than of those over its spurs.

shallow lakes. This trough is more than nine miles long; yet the Silsersee, at its upper end, is only 66 feet higher than the St. Moritzersee; hence the fall is only 15 in 10,000, or, roughly speaking, about 7 feet in a mile. The Maloja Kulm is a very short distance from the head of the Silsersee and only a few feet higher than it.[1] . . . But no sooner have we traversed this low ice-worn floor of rocks than the scene changes in a moment. We are standing on the brow of a series of lofty cliffs: the road swings away to the left to seek a less precipitous part of the enclosing head of the valley; to the floor of which—nearly a thousand feet below—it descends by a series of zigzags. To what are we to attribute this singular configuration: this flat, almost level trough, driven right through the crest of the Alps, and terminating so abruptly at the brink of a range of precipices? . . . I believe that in this part of the valley of the Inn we have a true valley of erosion, comparable, let us say, with the upper part of the Val Roseg, one of those steps which not unfrequently precede the final ascent to the watershed. But I suppose that the watershed in this case once lay some distance farther south . . . say somewhere above the site of Vico Soprano. From this ridge the Inn then flowed towards the north-east, while, on the other side, the Maira descended toward the south-west."[2] The average fall of this river from the Kulm to Vico

[1] The height given for the lake is 5,872 feet, for the pass 5,942, but I believe the latter does not indicate the lowest point in the bed of the valley, and that a very shallow cutting would suffice to divert to the Adriatic the waters of the Silsersee.

[2] The Author: *Alpine Journal*, vol. xiv. p. 225.

Soprano is 1 in 10, and from the latter place to Chiavenna—some twelve miles farther—is 1 in 24; while the fall of the Inn, even between Samaden and Finstermünz, is rather less than 1 in 100. Besides this, the rainfall is heavier on the Italian side, so it is obvious that even if the two rivers were "started fair" the "streams of the Maira would bite more deeply into the dividing range than those of the Inn. The intervening mountain mass was quarried away far more rapidly on the southern side, until at last the corrie at the head of the Maira ate its way back through the dividing ridge and actually cut away the slopes by which the streams descending to the Engadine were formerly fed. Thus I regard the floor of the upper Innthal as the decapitated remnant of a very ancient valley, which, while important changes have been occurring on either side, has remained comparatively unchanged, because denudation must needs cease when its motive forces are gone." An examination of a good map of the district confirms this explanation. The tributary glens of a river system tend to converge in the direction of the flow, as, in a tree, twigs unite with branches and branches with the trunk. But the long glens occupied by the Albigna and Forno Glaciers run due north, though they drain into the Maira in almost the opposite direction. "Moreover, the mouth of the upland glen leading to the Forno Glacier is as nearly as possible on the level of the Maloja Kulm: its floor is reached from the latter by a track which keeps nearly at the same level, though the torrent which plunges downwards to the Maira has gashed the rock over which it rushes. Hence I believe that the streams from the Forno and Albigna glens formerly flowed into the Innthal, as those from the Fédoz and Fex still do, but that as the corrie at the head of the Maira gradually receded in a north-easterly direction, it intercepted and diverted, as its floor was on a lower level than theirs, first the torrent from the Albigna glen and then that from the Forno." It is, in fact, a case of capture, to use the phrase which has become common since the above words were written—one of the most obvious to be found in the Alps.

The Toblacher plateau, the watershed between the Drave and the Rienz, a tributary to, and probably once a more important stream than the Eisack, also affords an instance of a removal of landmarks, and a second one occurs in its immediate neighbourhood. The watershed on the former, though between the Adriatic and the Black Sea, is curiously ill-defined. It is on "a flattish, drift-covered plain, barely 4,000 feet above the sea, perhaps a third of a mile wide, which is guarded on the one side by the crystalline schists of the central range of the Tyrol, on the other by the magnificent dolomitic cliffs of the southern range. On the west, from Welsburg to Niederndorf (four miles) there is a rise of about 260 feet; from the latter place to Toblach (three miles) is a further rise of 150 feet; and from Toblach to Innichen, on the east side (two miles) a descent of less than 100 feet. Thus the floor of the trough for some five miles does not rise and fall much more than about 100 feet, and the average slope is less than 1 in 100. In the next eight miles the fall is only about 225 feet, which is still more gentle. But then it becomes more rapid: the valley contracts, the floor descends more sharply, as the river passes through the Lienzer Klause, a defile cut into the crystalline schists about nine miles long. Lienz itself, twenty-eight miles from Toblach, is about 1,750 feet below that place.[1] . . . Hence I conclude that the original watershed must be placed to the east of the Toblacherfeld, and that the Drave has cut its way back into the upper part of the glen of the Rienz." The other instance is within ten miles of the highest point on the Toblach trough. Close to this the road to Cortina d'Ampezzo turns off to the south and soon enters a deep trench in the dolomite mountains, called the Höllensteinerthal. On either side magnificent peaks attain a height of between 10,000 and 11,000 feet above the sea. From the entrance of the glen the rise to Landro by the "shallow Durrensee, in which the crags of the Cristallo are mirrored, is less than 600 feet, though the distance is full six miles; and for the remaining six miles the total ascent is hardly more than 250 feet."[2] The trough is then, as at the Maloja Kulm, suddenly interrupted. From the northern, or rather the north-western, side of Monte Tofana, a glen comes sweeping round, the floor of which is some hundreds of feet below the level of the pass. To this a steep and narrow track was the only means of descent prior to the construction of the present road, with its series of zigzags. "Here, then, we have a repetition, though on a smaller scale, of

[1] Untervintl, about the same distance as Lienz on the other side of Toblach, is about 300 feet nearer the level of the latter.

[2] That is about 870 feet from the Toblach watershed, an average slope of under 1·5 in 100.

the physical features of the Maloja; and here, also, I can find no other explanation of the apparent anomaly than that the watershed once lay farther to the south, and that as the main feeder of the Piave deepened the valley between the Tofana and the Cristallo *massif*, it gradually cut away the rocky wall which once closed the glen to the west of Schluderbach." [1]

But the Pennine range near Monte Rosa supplies us with a more gigantic, though at first sight less obvious, parallel. "Between the pyramidal summit of the Matterhorn and the *massif* of the Breithorn [2] there is the marked depression crossed by the Théodule Pass—a breach in the rocky wall, which is some two or three thousand feet deep. . . . From the Breithorn the rocky rampart continues, practically unbroken, in a general easterly direction, as far as Monte Rosa; its peaks being well over 13,000 feet in height, and even the gaps between them only about 1,000 feet less elevated. In fact, from the Breithorn to Monte Rosa the crest of the range is never less than 12,700 feet above the sea." It culminates in the vast ridge of the latter, the highest peak of which is 15,217 feet above the sea; after that the watershed between Switzerland and Italy runs north, and we find another gap similar to the one just mentioned, except that here a comparatively level snowfield is terminated by abrupt precipices on the eastern side. Every one who has crossed by one of the Weissthor passes, or has

[1] *Loc. cit.*, p. 227.

[2] The Matterhorn is 14,781 feet; the Breithorn 13,685 feet, and the Théodule Pass 10,899 feet, but the intervening range nowhere exceeds 11,400 feet.

ascended the well-known snowy hump of the Cima di Jazzi, will remember the startling contrast between the long and gentle ascent over slopes of snow on the western flank and the precipitous descent on the Italian side. "Between Monte Rosa and the Strahlhorn (13,750 feet) there is a gap of about three miles wide, the flattened crest of which undulates a little on either side of 12,000 feet. Besides this, a line of peaks only slightly subordinate to that of which Monte Rosa forms a part, terminates abruptly with the Strahlhorn almost on the watershed instead of being prolonged, as might have been anticipated, by a spur on the southern side. Of this apparent anomaly we have not far to go in order to find an explanation. The head of the Val Macugnaga, which is a huge corrie, has cut back into the *massif* of Monte Rosa, and is partly enclosed by its eastern spur, which runs towards the Pizzo Bianco. The drainage from this corrie, starting in a northerly direction, sweeps round toward the east, passing under the great wall of cliffs, which, as already mentioned, descends from the edge of the snowfield feeding the Gorner and the Findelen Glaciers, and from that at the head of the Schwarzberg Glacier, east of the Strahlhorn. Hence I conceive that the Strahlhorn was once part of a great spur thrown off from a range which extended in a direction rather east of north from Monte Rosa, and was elevated perhaps a couple of thousand feet above the present edge of the Gorner snowfield. The Cima di Jazzi might be a remnant of another spur from this range,[1] and it is a noteworthy fact that

[1] Orographically this is important, for it is prolonged due west, beneath the snowshed between the Gorner and Findelen Glaciers, to

the Monte delle Loccie, a peak over 12,000 feet on the eastern spur of Monte Rosa, is almost exactly on the line of the Strahlhorn axis.[1] This range has been cut away, as the great glen of Macugnaga was being deepened and enlarged, devouring the mountain group by which it is fed." Strange as it may seem, I believe that the Swiss-Italian watershed (if the phrase be permitted) of this part of the Pennines once passed high in air with an eastward curvature from the Signalkuppe of Monte Rosa to the Strahlhorn, and that the Val Anzasca has cut its way back through this, and has even bitten off some of the upper snows of the Schwarzberg Glacier. An examination of the map suggests that the heads of the Val Sesia, Val de Lys, and Val d'Ayas have done the same, though on a comparatively small scale, and the gap between the Breithorn and the Matterhorn may be largely due to the simultaneous recession of the principal feeder to the last-named valley and of the Val Tournanche. It must not be forgotten that the lofty range connecting the Matterhorn with the Dent d'Hérens (13,715 feet) runs almost due west, and is part of the watershed of the Pennines. The map suggests that one feeder of the Val Tournanche and the Val Pelline have tried to be trespassers, though the latter has met with little success. It is certainly remarkable that a great spur, which for some distance hardly sinks below 12,000 feet, runs southward from the Dent

the Stockhorn (11,595 feet), the Gorner Grat (10,289 feet), and the Riffelhorn (9,617).

[1] Possibly the curious shelf or trough of the Schwarzberg Weissthor (11,851 feet) is really one half of the old pass between the Strahlhorn and a missing peak.

d'Hérens between the above-named valleys, while nothing of any importance proceeds in that direction from the Matterhorn. Neither does it anywhere on the south side of the watershed in this part of the Pennines, while the contrary is true of the northern. Here, restricting ourselves to the drainage system of the Visp, where the structure is a little less complicated than on either side, we find the grim Dent Blanche (14,318 feet) rising due north of the Dent d'Hérens, from a spur which runs generally in that direction. Another great spur, though now completely isolated by the deep trench of the Zmutt Glacier (a very large one, which has been a considerable trespasser westward), seems once to have been similarly connected with the Matterhorn; for its southernmost peak, the Ober-Gabelhorn (13,365 feet) is almost due north of the latter summit. It is continued in that direction, never sinking much below 12,000 feet, and generally rising well above this, till it towers up in the huge pyramid of the Weisshorn (14,804 feet). Another great spur, dividing the two arms of the Visp, extends northward from the Strahlhorn, and culminates, east of the Weisshorn, in the Mischabelhörner, a line of closely linked peaks, of which the Dom attains 14,942 feet, thus being the highest mountain wholly in Switzerland. On the eastern side of the Saas-Visp is another north-running spur, which at first sight seems exceptional, because its summits, which start from the watershed east of the Monte Moro Pass (itself only 9,390 feet) are at first comparatively unimportant; but they begin to assert themselves with the Portjengrat (12,005 feet). After this peak the crest sinks at the Zwischbergen Pass to 10,657 feet, then culminates in the Weissmies (13,225 feet); north of which come the Laquinhorn and the Fletschhorn, both only little below it. So we can understand the reduced height of the southern part of the spur, when we remember the encroachments of the Val Anzasca, and perceive that the feeders of the Antrona valley have been following its example, though on a much humbler scale.

But we must return to the trough-like passes from which we have been diverted by this question of trespass. All the great roadways over the main chain, from the Mont Genèvre to the Brenner, show this trough-like structure more or less clearly; and the descent on the Italian side is the more rapid, though less conspicuously than at the Maloja. It is not, as a rule, so well marked in those crossing either one of the great lateral ranges or from one valley to another parallel with the watershed—as at the Furka Pass—for such cases as the Gemmi (a mule track) are due to trespass. By this principle also we can explain another very common feature—that peaks often rise, not on the watershed itself, but on bastions which project slightly from it, generally on the Italian side. Monte Viso affords the most conspicuous example, for instead of crowning the watershed between France and Italy, which runs for some distance at a height of from nine to ten thousand feet, it is severed from that by a ravine which is probably about a thousand feet in depth. Examination of a map shows that the apparent anomaly of a peak over 12,600 feet in height in this isolated position is due to the retrogressive action of the feeders of the

Po on its northern and of the Vraita (the more active) on its southern side.[1]

To return for a moment to the central part of the Pennines in the neighbourhood of the Vispthal. Here, perhaps, more than in any other part of the Alps, we can realise both the grandeur of the mass from which their peaks and valleys have been carved and the vast amount of denudation. The Matterhorn and the Weisshorn are but little below 15,000 feet; the crystalline rocks begin to rise from the Italian plain at a level of about 800 feet, and from the Rhone valley of about 1,700 feet. Assuming that there has been no great change of level since those elevations were attained, the Alps have been carved out of a great semicylindrical[2] mass, the sagitta of which was nearly three miles and the chord well over fifty miles.

Valleys have been carved in this mass, the beds of which, after a course of some six miles from the watershed (say 15,000 feet), have dropped down to about 5,000 feet above sea-level—or in other words, 10,000 feet of rock must have been carved away from above either Zermatt or Saas Grund. Of course the original form of the surface may not have been quite so simple as has been assumed. Between the Matterhorn-Monte Rosa and the Weisshorn-Mischabel axes, both mainly hard gneisses, there is, in the neighbourhood of Zermatt, an infold of softer crystalline schist, but

[1] See the sketch map illustrating an article in "Peaks, Passes, and Glaciers," 2nd series, vol. ii. p. 132.

[2] Whether the boundary was elliptical or circular, we have no means of knowing; the peaks also may have been reduced by denudation, but then they may have continued to rise. Thus we are forced either to make this assumption, or to give up the problem as hopeless.

the area which it occupies is limited compared with the others, and thus would probably be a detail of minor importance.[1]

The amount that has been removed must greatly exceed that which remains, and a large part of this work must be attributed to rain and rivers rather than to snow and ice. This brings us to the question of what amount is to be assigned to the latter, and especially to the erosive action of glaciers. The following quotation from the lecture on which I have already drawn largely may serve as a succinct statement of the conclusions to which I have been led by many years' work in the Alps. "The present line of the watershed roughly indicates the crest of the Miocene Alps, which was probably in elevation not inferior to that which still remains. . . . The process of mountain-making was not yet ended. In Pliocene times another series of thrusts, acting outward from the basin of the Italian plains, still occupied by the sea, told with greatest effect upon the northern zone, especially on the quadrant between the latitude of Turin and the longitude of Ulm, thrusting up parts of the western chain, elevating the newly deposited beds on the Alpine border, and puckering up the Jura. That the process of sculpture was continued, until at last, prior to the great extension of the glaciers, the Alps had arrived at very nearly their present condition. . . ."[2] In close connection with this epoch, prob-

[1] No account is taken of the sedimentary rock removed, though this must have been considerable, because there is no means of estimating it, and a good deal of that work may possibly have been done before the dome emerged from the sea.

[2] *Loc. cit.*, p. 234.

ably in the later part of it, there were some slight disturbances in the same general direction as before, so that by a folding parallel with the axes of the ranges the beds of the valleys were relatively somewhat depressed, and in these minor folds the existing larger lakes accumulated.

Till about fifteen years ago the latter was the main point of dispute among geologists; one party, at times the larger, holding with the late Sir A. Ramsay that practically all the Alpine lakes, great and small, were results of the erosive action of glaciers; others, among whom I was one, maintaining the view just stated, and attributing only certain tarns, in peculiarly favourable situations, to ice-excavation. But now a large number of authorities maintain that, during the Ice Age, the depth of the Alpine valleys was increased by about a thousand feet, more or less; so that at present the main point of dispute is whether the steep-sided trench already mentioned and (as some would say) a portion of the more open part above, have been added to them since the beginning of the glacial epoch, or are in the main anterior to it.

River denudation depends principally on the strength and the velocity of the streams. Alter the one or the other, and you alter the form of the valleys —thus the change from the saucer-like curve of the upper parts to the V-like trench of the lower would indicate a more intense action of the carving tools. During four episodes in the Ice Age, as we have already said, the temperature fell considerably below its present average, and during the intervening three reverted very nearly to it. In the latter, denudation would proceed very much as at the present time; in the former, it would be either more or less, and which of these can, perhaps, best be determined by considering some hypotheses of recent date as to the mode and amount of sculpture in an Ice Age.

Certain geologists in America and in Germany have attributed to the action of snow and glaciers the following features—corries and cirques, the formation of many valleys, the deepening and enlarging of others. According to this school of geologists a corrie or cirque is thus produced: The existence of an elevated mound-like tract of land, which is just beginning to rise above the snow-line, is assumed at the outset. Since it has already suffered slightly from denudation,[1] there are inequalities on its surface which are favourable to the local accumulation of snow. "This, by melting and freezing, would soften and corrode the underlying material, which would then be removed by rain and wind, gravitation and avalanches. In course of time the hollow thus formed would assume more and more the outlines of a corrie or cirque by eating into the hillside. With an increasing diameter it would be occupied, as the temperature fell, first by a permanent snowfield, then by the *névé* of a glacier."[2] Two new processes are now initiated to convert this depression into a regular corrie or a cirque; these are termed "sapping" and "plucking." "While ordinary glacier scour tends," as we are told, to produce "sweeping curves," and eventually a "graded slope," sapping produces "benches and cliffs," its action being horizontal and backwards and often dominant over scour.

[1] I should have thought it would have been rather considerably scarred.

[2] President's Address, British Association, 1910, p. 6.

The author of this hypothesis[1] convinced himself of its truth by descending a bergschrund 150 feet deep in the Sierra Nevada, which opened out, as is so common, beneath the walls of a cirque. The chasm ultimately reached the rock, which for the last 30 feet formed one of its walls. "It was in all stages of displacement and dislodgment, some blocks having fallen to the bottom, others bridging the narrow chasm, and others frozen into the *névé*. Clear ice had formed in the fissures of the cliff; it hung down in great stalactites, it had accumulated in stalagmitic masses on the floor." Here, we are told, there would be, at any rate for a considerable part of the year, "a daily alternation of freezing and thawing. Thus the cliff would be rapidly undermined and carried back into the mountain slope, so that before long the glacier would nestle in a shelter of its own making." As temperature must be uniform beneath the *névé*, its action, so far as this kind of work is concerned, must be protective; but here another agency begins to act —that of "plucking." "The ice grips, like a forceps, any loose or projecting fragment in its rocky bed, wrenches that from its place, and carries it away. The extraction of one tooth weakens the hold of its neighbours, and thus the glen is deepened by plucking while it is carried back by sapping. . . . As the cirques receded, only a narrow neck would be left between them, which would ultimately be cut down into a gap or col. Thus a region of deep valleys with precipitous sides and heads, of sharp ridges, and of more or

[1] W. D. Johnson, "Science," new series, ix. (1899), pp. 106, 112.

less isolated peaks, is substituted for a rather monotonous, if lofty, highland." [1]

I believe these processes to be largely imaginary.[2] The temperature in the lower part of a bergschrund would be comparatively uniform, and the floors of corries or cirques, of which glimpses may be obtained in the smaller (they are often masked by débris, which of course came after the *névé* had melted), show no signs of "sapping" or "plucking," but some little of abrasion by moving ice.

Cirques and corries also not unfrequently occur on the sides as well as at the heads of valleys; such, for instance, as the two in the *massif* of the Uri Rothstock on the way to the Surenen Pass and the Fer à Cheval above Sixt. The Lago Ritom lies between the mouth of a hanging valley and a well-defined step, and just above that is the Lago de Cadagno in a large, steep-walled corrie, which opens laterally into the Val Piora, as that of the Lago di Tremorgio does into the southern side of the Ticino valley. Good examples of cirques are more abundant in the calcareous than in the crystalline districts, because, from a variety of causes, the former rock is more favourable to their formation than the latter, and we find them of all sizes,

[1] I believe this to be a true history of the making of peaks and valleys, provided we take water instead of ice as the main agent, and remember that as a rule the process would begin at a very early stage in the mountain history. The advocates of the above-mentioned view admit the possibility of this, but suppose the mountain to be a kind of palimpsest. Nature had effaced her earlier sculpture, and worn down the earlier features, till there was nothing more to grasp. Then a change, either of meteorological conditions or of level, enabled her to begin work again.

[2] The Author, *Quart. Jour. Geol. Soc.*, vol. lviii. (1902), p. 690.

from a few to many hundreds of feet in height, and from yards to furlongs in diameter.[1] "Cirques may also be found when glaciers have had a comparatively brief existence, as the Creux des Vents in the Jura; or have never been formed, as, for instance, on the slopes of Salina, one of the Lipari Islands, or in the limestone desert of Lower Egypt. On all these the same agent, plunging water, has left its marks — runlets of rain for the smaller, streams for the larger; convergent at first, perhaps by accident, afterwards inevitably combined as the hollow widened and deepened. Each of the great cirques is still 'a land of streams,' which are kept in action for the larger part of the year by beds of snow on the ledges above its walls." [2]

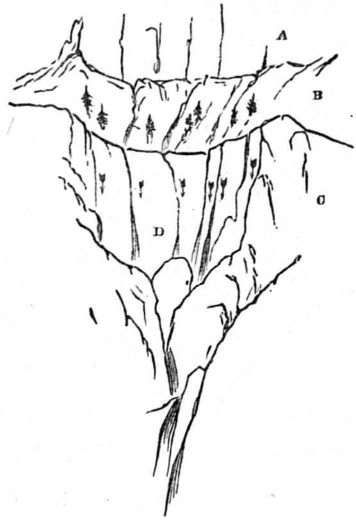


FIG. 11.—SMALL CIRQUE NEAR ENGELBERG.

A Limestone cliffs.
B Shaly bank with trees, &c., out of which the stream breaks.
C Limestone cliff.
D Cirque, drained by a cascade.

The steps already mentioned as existing in the floors of valleys, though attributed to "sapping and plucking," really land advocates of the process, as it seems to me, in a serious difficulty. They are supposed to indicate stages at which the excavating

[1] Many examples also occur in the Pyrenees; those of Gavarnie and Troumoose being, perhaps, the most noted.

[2] Address, p. 8.

glacier transferred its operations to a higher level. " But if so, the outermost step must be the oldest, or the glacier must have been first formed in the lowest part of the incipient valley. Yet with a falling temperature the reverse would happen ; for otherwise the snow must act as a protective mantle to the 'mature' pre-glacial surface almost down to its base.

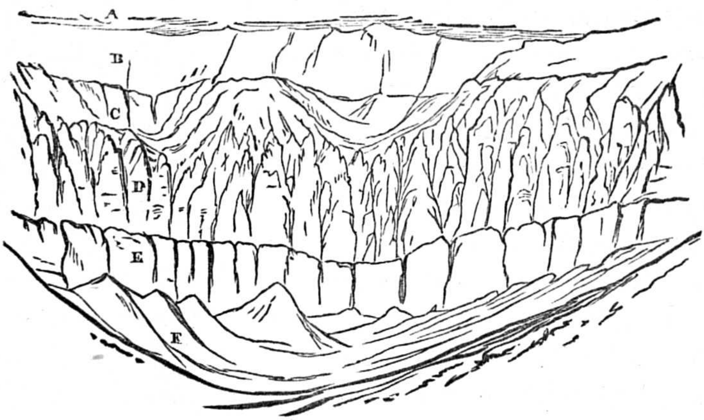


FIG. 12.—EASTERN CIRQUE BENEATH THE URI ROTHSTOCK.

A = Clouds concealing peaks.
B = Limestone cliff.
C = Shaly slope with small corries and snowbeds.
D = Shaly cliffs furrowed by streamlets.
E = Limestone cliffs slightly grooved by streamlets.
F = Floor of cirque with talus-heaps at side.

However much age may have smoothed away youthful angularities, it would be strange if no receptacles had been left higher up to initiate the process, and even if sapping had only modified the form of an older valley, it could not have cut the steps unless it had begun its work on the lowest one. Thus, in the case of the Creux de Champ, if we hesitate to assume that the sapping process began at the mouth of the valley of the Grande Eau above Aigle, we must suppose it to have started somewhere near Ormont Dessus, and to have excavated that gigantic hollow, the floor of which lies full 6,000 feet below the culminating crags of the Diablerets." [1]

It might, however, be maintained that even if "sapping and plucking" had done but little in the cutting out of cirques and corries, the glaciers of the Ice Age had greatly deepened the valleys of mountain regions. That view has been advocated by Professors Penck and Brückner,[2] and deserves careful consideration, though I should object at the outset that the physical connection of the cirques and corries with the valleys suggests that the making of the one and the other was practically simultaneous. But waiving that difficulty, though to myself it seems insuperable, let us see how the hypothesis works out in some of the Alpine valleys. "On one point all parties agree, that a valley cut by a fairly rapid stream in a durable rock is V-like in section. With an increase of speed the walls become more vertical; with a diminution the valley widens and has a flatter bed, over which the river, as the base-line is approached, may at last meander. Lateral streams will plough into the slopes, and may be numerous enough to convert them into alternating ridges and furrows. If a valley has been excavated in thick horizontal beds of rock varying in hardness, such as limestones and shales, its sides exhibit a succession of terrace walls and shelving banks, while a marked dip and other domi-

[1] *Ut supra*, p. 8.

[2] *Die Alpen im Eiszeitalter*, 1909, a large book the value of which as a storehouse of facts I gladly acknowledge, though I cannot accept some of its chief conclusions.

nant structures produce their own modifications. It is also agreed that a valley excavated, or greatly enlarged, by a glacier should be U-like in section."[1] Granting that there is clear evidence that the larger Alpine valleys, with many of their tributaries, have been filled by ice from very nearly the present level of their torrents up to a height of some couple of thousand feet above them, let us see what forms dominate among them. It will suffice to select one case from a crystalline and another from a limestone district, out of the many with which my note-books are crowded. For the former I select the valley of Saas, in which I have spent the largest part of three summer holidays during the present century. Here, as already said, there is a marked change of slope, roughly corresponding with the lips of the hanging valleys, and from about 800 to 1,000 feet above the level of the main torrent. These valleys in some cases, such as the Fee glen, and perhaps that above the Trift Alp, are rather broad and slightly flat-bottomed, but so also are a few comparatively small and shallow glens at a rather higher level, in which glaciers do not now exist, and have not left any marked traces. These might be claimed as U-like in section; but we must not forget that, as has been pointed out, this is the common pattern in those higher parts of the enclosing mountains which are not usually attributed to ice-work, and so may be assigned to the post-glacial ages; but other valleys, such as those on the right bank leading to the Zwischbergen and the Antrona Passes, are distinctly V's. In the former, this shape is rather enhanced by the great amount of screes (postglacial); but rock

[1] *Ut supra*, p. 8.

From a photo by] [*Mr. J. J. Lister, F.R.S.*

21. VIEW DOWN THE SAAS-THAL.

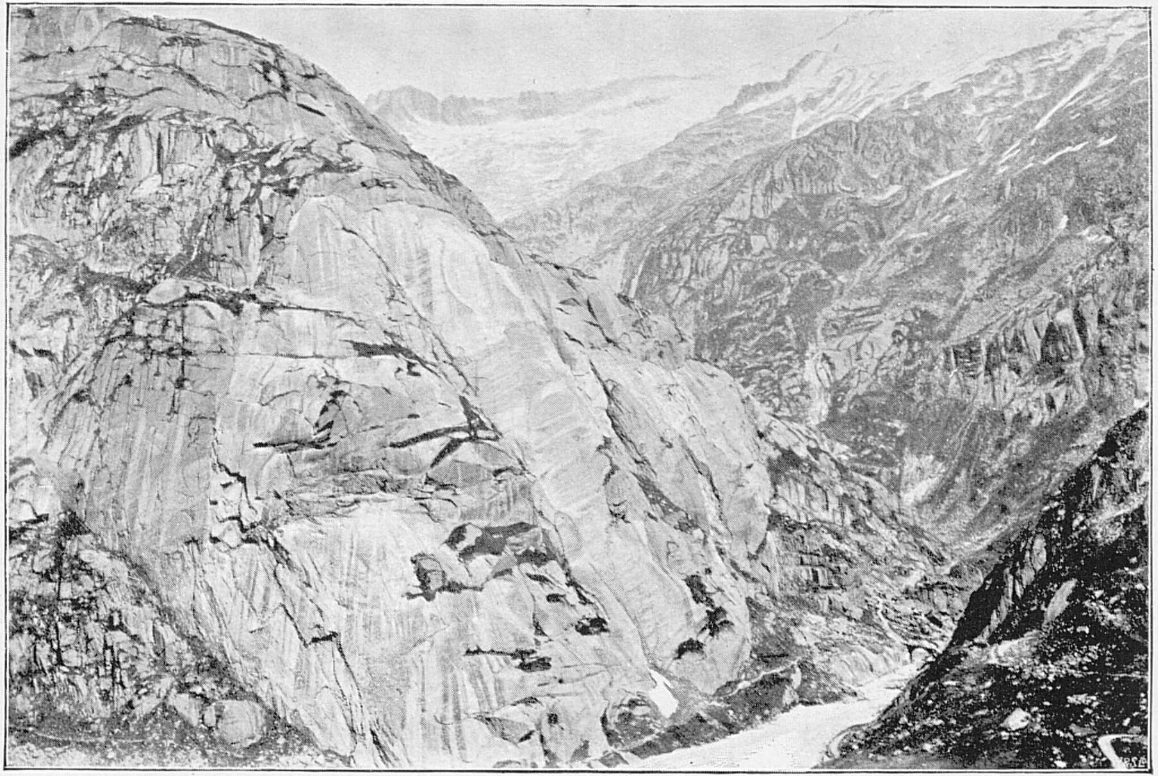
To face p. 186.

projects from them in so many places that I feel no doubt as to its true outline. Those projections also, while they bear the marks of glacial abrasion, show that it has not obliterated the original features—ridge and furrow—of subaerial denudation. In the latter valley, where there is not so much scree, the same form is obvious, and the most that could be claimed for the work of ice is a slight blunting of the point at the bottom of the V. The slopes of the sides in both valleys exhibit the usual gentler curves, like parts of a catenary, above the steeper portions, and that form, as already said, is exhibited all down the main valley; the lips of the hanging valleys, especially where glaciers still remain, being notched by gorges—a grand one, cut down to the level of the Visp, coming from the Fee glen; shallower and shorter in other cases; while in the main valley ice-worn rock can be seen in many places, not only high up on its sides, but also down to within a yard or two of the torrent.

"Thus valley after valley in the Alps seems to leave no escape from the following dilemma: Either a valley cut by a glacier does not differ in form from one made by running water, or one which has been excavated by the latter, if subsequently occupied, is but superficially modified by ice. This, as we can repeatedly see in the higher Alpine valleys, has not succeeded in obliterating the physical features due to the ordinary processes of erosion. Even when its effects are most striking, as in the Spitallamm below the Grimsel Hospice, it has not wholly effaced these features; and whenever a glacier in retreat has exposed a rock surface, that demonstrates its inefficiency as a plough. The evidence of such cases has been pronounced inadmissible, on the ground that the glaciers of the Alps have now degenerated into senile impotence: but in valley beds, over which they passed when in the full tide of their strength, the flanks show remnants of rocky ridges only partly smoothed away, and rough rock exists on the 'lee-sides' of ice-worn mounds which no imaginary 'plucking' can explain. The ice seems to have flowed over rather than plunged into the obstacles in its path." [1]

This is true of the limestone districts of the Alps, no less than of the crystalline, though the steep cliffs of the former rock in such a place as the valley of Lauterbrunnen are often quoted as proofs of the trough-making tendency of a glacier. But they are rather the outcome of the cliff-making proclivity of limestone. The larger valleys of the Oberland frequently show us a wall of rock impending above the valley floor, but presently it mounts along one of the lateral slopes, without appreciable change in aspect, until it runs out "into the air" far above the highest possible level of the vanished ice. Instances of this are common in most of the valleys between the Diablerets and the Glärnisch (to restrict myself to the Swiss Alps), but at Lauterbrunnen the level is maintained for a rather greater distance than is usual. The vast wall of precipices which looks down upon the green slopes on either side of Grindelwald brings us face to face with more than one grave difficulty in the ice-erosion hypothesis. The huge limestone fortresses of the Wetterhorn, the Mettenberg, the Eiger, and the Jungfrau are separated, in the case of the first, second, and third, by deep valleys which, within my

[1] *Ut supra*, p. 9.



From a photo by] [*Mr. J. Eccles, F.G.S.*

22. ICE-WORN ROCKS NEAR THE GRIMSEL.

To face p. 188.

memory, were wholly occupied by glaciers.[1] These have now retreated, laying bare a corresponding structure, but it will suffice to describe that at the Lower Glacier. On either side of this the mountain rises in a series of limestone crags, presenting, especially on the right bank, a slightly "stepped" outline. The retreat of the ice has exposed two steps, with precipitous faces and ice-worn, gently sloping, treads, formed by slightly separated beds of limestone. These are severed by a profound gorge,[2] cut by the torrent from the glacier, which is now made accessible, and into which the ice fits like a wedge. Steps and edges are smoothed by the passage of the glacier, but the latter are only rounded.[3] Granted that the glacier is now effete, no one can deny that it passed over these two edges in the latest and almost the greatest of its advances—the Würm. How, then, did it contrive to make these steps, for to do that it must have been able to "cascade" like water? The answer may be that they were made in the Riss-Würm interglacial age. That explanation not only, as we shall see, introduces new difficulties, but also, in my opinion, proves too much. The crags of the Wetterhorn, the Mettenberg, and the Eiger rise almost vertically from the slopes of the Grindelwald valley to at least 10,000 feet above sea-level. Immediately on the left bank of the Lower Glacier a

[1] The Lower Grindelwald Glacier came down to the bed of the main valley in 1858. I made a rough sketch of the terminal ice-cave, which I still have.

[2] It cannot be less than 600 feet, but it is not easy to fix the exact point where the glacier ends.

[3] A sketch, made in 1870, shows it resting like a thick, stiffish quilt against the edge of the upper step.

wedge-like spur from the last named mountain terminates with an acute gable-end at little below that elevation and rises thence as a limestone arête to the summit (13,040 feet). From this it descends in a practically unbroken wall for something like 6,000 feet, and even the wedge-like end of the buttress just mentioned cannot be less than 3,000 feet above the slopes of meadow and pine wood (at first rather interrupted by crags) which come down from the Great and the Little Scheidegg to the bed of the Lütschine (2,915 feet). This vast crag is so similar from its top to its bottom that it must be mainly due to one agent, and water is the only one of which I can discover any trace. This great precipice shows three or four very shallow combes or recesses—embryonic cirques—which can only be explained by the cutting back of the cliff by ordinary weathering and dribbles of water from melting snow on little ledges above. These when collected into a single stream, can be traced by a small furrow in the slopes below. The latter are partly talus, but are mainly due to the outcrop of a softer shaly or slaty rock—like some of the larger longitudinal valleys already described. Thus the persistency of form in these great peaks makes it impossible, so far as I can see, to draw a line below which we can assign everything to the excavatory work of glaciers. Again, on following the Lütschine down to the Zweilütschinen junction, we find the Ortweid glen is a true V, though it once or twice has a small strip of nearly level land at its base. Its sides exhibit crags and slopes alternating up to their skyline, and there are two distinct drops of its bed in a seven miles' fall of perhaps 2,700 feet, the lower of which must be about 500 feet. Also below

Zweilütschinen the joint valley—one arm of which is so open at Lauterbrunnen—narrows for a while and becomes a true V, again opening out before reaching Interlaken. This town, we must not forget, stands on a joint delta formed by the Lütschine and the Habkerenthal streams, so that the true floor of the valley must lie fully 700 feet beneath the almost level surface.[1]

It has, however, been recently contended that though these steps in valleys cannot have been cut by glaciers, they were made by streams from them in the interglacial stages of the Ice Age, and thus mark halting places in their retreat or advance. I agree with my friend Professor Garwood, who has recently advanced this view,[2] in considering the action of snow to be generally conservative and glaciers, though to some extent abrasive, to be much less effective than running water, but feel doubtful whether the step was produced quite as he supposes: namely, that above its present edge the valley floor was protected by névé or glacier, but below it has been exposed to denudation by water, which was abundantly supplied by the melting ice, and would acquire in process of time more and more of a plunging action. Thus he regards those V-like valleys, a thousand feet, more or less, in depth, together with the associated steps and hanging valleys, as results of water-erosion during interglacial times; thus placing the preglacial floors of the Alpine valleys at the above-named height above the existing torrents.

[1] The greatest depth of the Lake of Thun is 702 feet; that of Brienz 860 feet.

[2] "Features of Alpine Scenery due to Glacial Protection" (*Journal of Royal Geogr. Soc.*, vol. xxxvi. (1910), p. 310.

I admit the difficulty of explaining precisely how these steps were formed, and hesitate to differ from one whose experience in the Alps and other mountains is so great, but I cannot help thinking that he overestimates the amount of erosion during the Glacial Epoch. The great masses of conglomerate (nagelfluhe) described in Chapter I. show that, by the beginning of Miocene times, the main Alpine valleys must have been cut down nearly to their present levels, unless we suppose the relation of these newer to the older rocks to have been greatly altered during the second epoch of mountain-forming, a question to which, as it has been already discussed,[1] I need only refer. But apart from this, we may fairly say that the ordinary estimates of geological time would not allow enough to accomplish the work. According to the curve of temperature given by Penck and Brückner, the latter was higher than now during rather more than half (0·53) of the Ice Age. But this Age only occupied about one-eighth of the whole time since the beginning of the Miocene, so the interglacial ages would cover about one-fifteenth, which, as I have elsewhere shown,[2] seems hardly adequate. If we admit with them that the truncation of spurs, and other evidence in the lower part of these V-like valleys, indicate the existence of a water-worn valley before the glacier came down it, then this must have been carved into its present shape either during the Riss-Würm interglacial stage or by combined effort during the three stages, or was mainly preglacial. But in the Limmat valley, to take one example, the Würm ice-stream had hardly any disturbing effect on the

[1] Chap. III. [2] Presid. Add., 1910, p. 12.

masses of gravel deposited during the preceding interglacial stage; and, so far as I am aware, there are no signs in those parts of the lowlands, over which the Riss ice-stream passed, that it seriously interfered with the subjacent rocks. But it may be urged that higher up the valleys erosion was continuous. If so, it would be more active in the Linth valley; yet the rise from the mouth of this to Glarus, a distance of about seven miles, is hardly more than 180 feet, the steeper ascent not beginning till above that town. The Rhine also, except for the small step, nowhere exceeding 60 feet, at the Falls below Schaffhausen,[1] extends with an unbroken bed far up into the mountain region. On the Rhone the first step is above Brieg, near Naters, where the bed of the valley rises about 700 feet. Professor Garwood relies much on the three steps in the Mesocco valley, leading to the Bernardino Pass. It is no doubt difficult to explain the mode of making the uppermost of these rock-steps, which rises for about 800 feet above the San Giacomo plain, and is notched by a stream on either side, but I cannot help feeling that his explanation seems a little too ingenious. It begins by supposing this step to be the oldest of the three. The retreating ice makes a long halt there, at about 5,300 feet, during which the numerous streamlets which it feeds set up a plunging action so as to cut out a rather precipitous bank, with the plain below on which St. Giacomo (3,845 feet) stands. During a retreat after another advance, the ice halts lower down the valley, at the top of the middle step, which is about 700 feet high, but is more gently graded and

[1] We can hardly reckon the Lauffenburg Rapids as a step.

thus less difficult to explain; while the lowest step, at Mesocco, is only about 300 feet and is less remarkable, except for the fact that the river appears at some time to have deserted its original channel to cut a gorge.[1] He quotes other instances, such as the step at the head of the Lago Ritom, the one which causes the Tosa Falls, and another in the same valley nearer to the Gries Pass. In fact, they are rather numerous in upper parts of valleys; in the lower I think they more often take the form of barriers such as will presently be noticed. I agree with my friend that the existence of ice (and still more of snow-beds), would be favourable to the formation of a step immediately beyond its margin; in fact, I am disposed often to regard a rock-step as a "straightened-out" cirque—that is, one where many small streams have worked in parallel lines instead of convergently.[2] A step, I take it, or a cirque, or indeed a cliff of any kind high up on a mountain side, cannot have been left, as we now see them, either by glacier or by river. They have receded, maintaining their wall-like aspect, being sapped from below by the destruction of their foundations, as the valleys were deepened, and cut back by the joint action of heat, frost, and water-drip.

[1] The change of channel prior to the cutting of a gorge is a common feature, as we shall see, in rock barriers.

[2] But a double step, such as those at the Grindelwald Glacier, would require us to assume (I suppose) that the ice first cut a step in the position of the lower one, but as high as the two together, then retreated a furlong or so and cut the upper one. But this seems rather too ingenious an explanation; and as the stream would have by that time got into a gorge (as now), the conditions of erosion would be much as they are at present.

From a photo by] [*Prof. E. J. Garwood.*

23. LAGO RITOM.

To face p. 194.

I should, therefore, offer a rather different account of the forming of these valley steps. Suppose the land to have risen in a low, flattened arch above the sea, as has been already described. Transverse valleys begin to form. The water, as it descends, passes from a softer to a harder bed. The stream begins to jump and plunge; that is the beginning of a step, which in process of time will grow in height, if the bed be thick. As the land rises the valley, now well marked, will be prolonged downwards, and the occurrence of another hard bed may repeat the process. Snow would, no doubt, be very favourable to the widening of a step. In a comparatively warm climate, where it falls only in occasional winter showers, which quickly disappear, its erosive effect is extremely small, for the water merely soaks into the ground; but when it lies thickly for two or three months, numerous streamlets are formed in melting, and that is favourable for cliff-cutting, just as their collected waters at a lower level are to valley-furrowing. These conditions would, no doubt, occur in the interglacial stages, but they would set in long before the Ice Age. The temperature about the middle of the Pliocene period was probably rather above its present average. If it were 6° higher, the snow-line would be at 10,000 feet, and any glacier that remained would be small; but even then snow would lie at about 4,000 feet above sea-level for as many months—probably three or four—as it now does at half that elevation; or in other words, the zones of cliff-cutting and of valley-furrowing would be moved 2,000 feet higher up the mountain slopes. But as the temperature fell prior to the first great advance of the ice, the beds of the upper valleys would be buried under snow and névé which have little abrasive or erosive power. The water draining from these would be small in amount; the cutting power of the torrents would be reduced. In the mountain valleys of the Alps the smaller streams, during the winter, are replaced by a pendent drapery of ice; while the main torrents—such, for instance, as the Reuss between Wasen and Göschenen—is reduced to less than half of its summer volume. In the Ice Age the bare crags—and of these much would still be exposed—would suffer meteoric denudation, but all that was buried beneath snow would be protected, until the névé had been transformed into a glacier. With a temperature 6° lower than now, denudation, except at one groove in the lip of the glen, would be almost at a standstill in the lower parts of the Fee, the Almagell, and the Antrona valleys, as well as in hundreds of others at or above the same level. Some authors have suggested that the Alps were considerably uplifted at or near the beginning of the Ice Age. That may have happened, but as it still remains to be proved, it cannot serve as the foundation for an hypothesis, and it is safer to deal with things as they are. We know of only one age in which notable alterations of level occurred, and this was late in the Miocene or early in the Pliocene.[1] Those deep V-valleys which have been already mentioned indicate such a one, so I think it more probable that they are the work of this latter period and thus mainly preglacial.

[1] A vertical movement, which in some places amounted to hardly less than 6,000 feet, must have taken a long time, so it cannot be precisely dated.

Barriers, which have some relation to steps and are occasionally cited as proofs of glacial excavation, must next be noticed. Familiar examples are the three in the valley of the Ticino, between Airolo and Biasca, the Kirchet in the Haslithal, the Sottaguda gorge in the Dolomites, and, on a smaller scale, the obstruction in the Rhone valley at St. Maurice, "where a key unlocks a kingdom." In these places the valley is blocked by a rocky mound rising rather rapidly to a considerable height—perhaps two or three hundred feet—above its floor, through which the river cuts its way. Both above and below it, this floor is generally rather level and wide—perhaps a quarter of a mile or even more. Some authors suppose a glacier to have dug out basins on either side, and then, either because of the greater hardness of the rock or from a tendency to a curvetting motion, to have, as it were, clambered over this part. The gorge often much resembles one of those under the end of a glacier and we can hardly doubt that it was cut by a torrent fed by melting ice; but in a fair number of cases, so far as my experience goes, a curious feature exists, that the chasm is not sawn in the lowest point in the ridge.[1] A glacier has passed over the barrier—that is indisputable—but whether it was the maker is another question. In the Ticino valley, the Stalvedro gorge, the uppermost and shortest, where the drop is, perhaps, 200 feet, cuts through a spur which projects from the left bank of the valley, since it is formed of gneiss harder than the adjacent schists. The valley above cannot be called narrow, while

[1] I am not sure about Sottaguda, for it is nearly thirty years since I saw it, but can answer for it in the others which are named above.

below it expands and has a comparatively level bed for the next six miles. The face of the spur is fairly steep on the western and conspicuously so on the eastern side, and the latter is well defined by a grassy glen which comes down to the right bank of the Ticino. The Faido gorge, which is on a much larger scale—for it is more than half a league long with a drop of at least 500 feet—is also formed by gneiss, which again comes from the left bank of the valley and for a long distance retains possession of both sides. Here also a well-marked but fairly broad glen, taking on the whole a northerly course, comes down towards Rodi-Fiesso, and the gorge at its lower end merges rather less rapidly than it began into a valley of more ordinary type, with a high cliff on the right bank, and on the other a lower and more sloping one. Below the gorge the valley of the Ticino continues fairly open for some five miles, in places almost flat-bottomed.[1] Below Lavorgo a spur from the right bank forms a third rock barrier, severed by the Biaschina glen, through which the Ticino descends in a series of little leaps. The eastern face of this barrier appears to be determined by the coming in of the Ticinetto valley. It is asserted that the absence of windings and the abundance of truncated spurs prove this part of the main valley to have been excavated by ice. Its course, no doubt, is rather unusually straight above and below the Faido gorge, but this is due in the one case to its following the junction of two kinds of rock which differ greatly in hardness, and in the other to

[1] A considerable amount of débris, almost certainly post-glacial, has come down from the left bank. The outline of the solid rock is probably a pointless V.

the gneiss being exceptionally "slabby" (the result of cleavage foliation), which constrains the stream to follow a rather straight course. But the valley winds occasionally, as we can see in ascending the path from Airolo to the Val Piora, and from one or two other places where a general view is obtained. Truncated spurs are not in themselves proofs of ice erosion. If a main torrent is more powerful than two of its tributaries and thus deepens its valley more rapidly than they can do, it must truncate the ridge between them, and of that several instances can be seen in the Ticino valley between the Stalvedro gorge and Giornico. Hence, after a recent careful examination of the ground, with which I was already fairly familiar, I agree with Professor Garwood [1] in maintaining that the lower part of that valley does not indicate the erosive effects of ice.

The gorge of the Aar cuts through a limestone ridge, and is both shorter and narrower than those of the Ticino. Like them, it has not been sawn through the lowest part of the barrier. In regard to this I endeavoured to show, in a paper published in 1898,[2] that the hypothesis of glacial excavation, unless we assumed the possibility, as its advocate virtually did, of "rotatory glaciers—whirlpools of ecstatic ice" [3]—proved, on a careful scrutiny of the ground, to introduce more difficulties than it explained, so that I may leave it and the other instances, without further notice, for the wider question of the erosion of lake basins.

[1] *Quart. Jour. Geol. Soc.*, vol. lviii. (1902), p. 703.

[2] *Alpine Journal*, vol. xix. p. 29.

[3] J. Ruskin, *Geol. Mag.*, 1865, p. 50.

The late Sir A. Ramsay, in a paper published in 1862,[1] attributed these basins, large as well as small, to the excavatory power of glaciers, and the advocates of this explanation would now probably command a majority of geologists. His arguments may be summarised under three heads:[2] (1) Lakes are abundant in glaciated regions; (2) glaciers are potent excavators; and (3) no agent but ice is competent to produce a lake basin. The first is true, and I have never denied that, under favourable circumstances, small lake basins—tarns, like that at the Grimsel, or in scores of places in the Alpine region, with the lakelets fairly numerous in our own mountainous districts and more so in Scandinavia—may have had this origin, though, as it seems to me, we begin to find serious difficulties in the Lake District of England and the larger lakes in the Highlands.[3] Some tarns, also, may be put aside at once as formed by moraines, which have blocked the course of a stream;[4] others may be the result of the removal of a rock-mass more soluble than those with which it is associated;[5] and there are others, such as crater lakes, which need not be considered. The main contention is over the great Alpine lakes—such as Maggiore, Lugano, Como, and Garda on the one side of the chain, or Geneva, Lucerne, Thun, Brienz, Zurich, Wallenstadt, and

1 *Quart. Journal Geol. Soc.*, vol. xviii. (1862), p. 185.

2 *Geographical Journal*, June, 1893.

3 Presid. Add., Sheffield, 1910, p. 9.

4 J. E. Marr, "Tarns of Lakeland" (*Quart. Jour. Geol. Soc.*, vol. li. (1895), p. 35).

5 E. J. Garwood, "Tarns of Canton Ticino," *Id.*, vol. lxii. (1906), p. 165. I think, however, that in some cases this explanation has been carried rather too far.

Constance on the other. As so much has been written on this subject, a very brief summary of the objections to the glacial excavation theory may suffice.[1] They are the following: That no valid proof has been given that glaciers, except under very special circumstances, are capable of excavating as distinguished from abrading; that the form of some lakes, such as Lucerne and Lugano, and the position of others, such as Zug, are difficult to reconcile with any such agency; that most of the larger lakes on either side are situated near the border of the chain, just where the glaciers remained for the shortest time. Professor Garwood[2] has recently ascertained for us the subaqueous configuration of certain of the smaller lakes; Professor Forel has thoroughly studied the Lake of Geneva;[3] M. Delebecque has sounded and described in a handsome volume the French Lakes;[4] The contours in many of these are difficult to explain on Sir A. Ramsay's hypothesis, for they resemble, both above and below water, those of ordinary valleys. Moreover, while in bringing forward his own view he successfully disposed of a number of antecedent hypotheses, he did not discuss one which, in my opinion, is its most formidable rival. Glaciers cannot be invoked for the excavation of Gennesaret and the Dead Sea, or of the Great Lakes of North America, or of those in Central Africa; these can only have been formed by differential movements in the

[1] See *Geographical Journal, ut supra. Quart. Jour. Geol. Soc.*, vols. xxvii. p. 312, xxix. 382, xxx. 479.

[2] "Tarns of Canton Ticino," *ut supra.*

[3] "Le Leman," vol. i.

[4] "Les Lacs Français," 1898.

beds of valleys. But the larger Alpine lakes, from the deeper part of Geneva to that of Constance on the one side of the chain, and from Maggiore to Garda on the other, could be formed in this way, for they occupy two broad marginal zones; thus the necessary movements would in no case exceed 1,200 feet on the northern and about 1,500 feet on the southern side. All that I have seen since the journeys undertaken to obtain the evidence embodied in the papers published from 1871 to 1874—and it has not been a little—has confirmed me in the view then expressed, that the work of glaciers is, as a rule, not more than abrasive, and is erosive only under special circumstances.

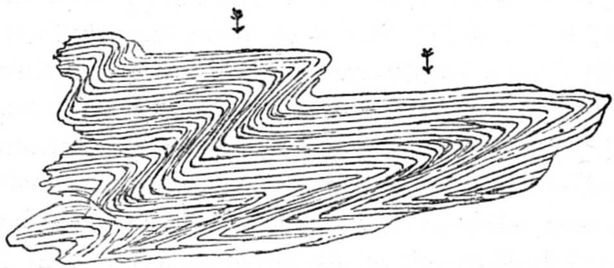


FIG. 13.—BLOCK OF CONTORTED QUARTZ-MICA-SCHIST.

(Quarry near Brunecken). Length about 1 foot. The arrows point to flat surfaces indicating original bedding, and the specimen illustrates on a small scale what the mountains often show on a very large one.

From a drawing by] [*Signor Edoardo Rubino.*

24. VAL TOURNANCHE, UPPERMOST PART.

To face p. 202.

VIII

THE WORK OF RAIN AND UNDERGROUND WATER

EARTH-PILLARS are the most conspicuous monuments of what rain alone can do. These are spire-like columns of hard mud, studded with rock-fragments and supporting a flattish capstone. Usually occurring in groups, which are sometimes linear, they are occasionally isolated, though this can only be when the rest of the mass of which they were once a part has been removed. The most noted instances are a few miles from Botzen, on a mountain named the Ritnerhorn, in the upper part of two of its valleys. Each of these is filled by a stiff clay containing many stones and rock-fragments, small and large. In this a stream has cut a glen, which is fringed on either side with numerous earth-pillars. At the first glance these rude obelisks seem "crowded like tombs in an overful churchyard, but on a closer inspection a method is seen both in the order and in the shaping of the pillars. Now and then one stands alone . . . but the majority are connected, and many of them form ridges of clay crested with pinnacles. Each is usually capped by a block of rock, like a turban; some, however, are bareheaded. On this block the existence of the earth-pillar depends; those which have lost their caps lose, not their heads only, but also their bodies. Here and there the clay-slope is furrowed by a rill, but for the most part the 'nullahs' between the ridges and the gaps between the pillars are perfectly dry in fine weather."[1] They are made in this way: The glen was formerly filled with a stony clay. Rills fed by rain worked at its surface and seamed it with furrows. Here and there one of these, in deepening its bed, encountered a boulder, by which it was presently divided. The current in each branch worked outwards, thus tending to isolate the stone. "Ribs of clay would be left between the rills, but as they would be attacked, not only on both sides, but also from above, by the rain, they would gradually disappear, and the boulders would remain exalted on pinnacles of stony clay. As their sides were exposed the rain would beat upon them and do something, in trickling downwards, to reduce their thickness, but the pillar for a long time is protected from serious harm by the capstone, as by an umbrella," until at last it slips off, when the pinnacle is gradually reduced to a hump and is then washed wholly away. In the Alps these pillars seldom exceed 8 or 9 yards in height, and are generally well under that; but in some countries they are considerably taller.[2] Miniature instances may also be found which are only an inch or two high, with a capstone no broader than a shilling or even a threepenny-bit. Such as these, where suitable material occurs, can be met with in other lands, including our own; but the first to catch my eye—in 1876—were in the Val de Lys

[1] "Story of Our Planet," pt. ii. chap. ii.

[2] Clarence King ("Mountaineering in the Sierra Nevada," chap. xii.) speaks of some on Mount Shasta from 100 to 700 feet high.

above Luchon in the Pyrenees. In the Alps ordinary earth-pillars can be seen on the north side of the Brenner, on the way to the Eggischhorn from Viesch (described by Sir C. Lyell [1]), on the right bank of the Visp almost opposite to Stalden, at Useigne in the Val d'Hérens, and in the valley of the Durance,[2] about four miles south of Briançon. In limestone districts the rain often seams the rock surface with innumerable channels, hardly larger than the gutters of a house-roof, and disappears down drain-pipes of its own making. Instances of these may be seen on the way to the Gemmi Pass, near the Dauben See (the water of which escapes down two or three of these vertical funnels), in the Dachstein region, and in many parts of the Styrian Alps; but probably none is more "remarkable for its extent and the absolute nudity of the surface" [3] than the Steinerne Meer. This is a limestone plateau, rather more than 7,000 feet above sea-level, some five miles in length and in most parts not less than two miles in breadth. The rock is weathered into innumerable holes, as if it had been once pierced by the roots of trees; it is furrowed by channels, which generally end in funnels, seldom more than a few inches in diameter. We passed only one or two down which a man could have fallen. Here and there was a streak of herbage, but generally only a few Alpine plants or a stunted, weather-beaten pine contrived to grow; for the most part it is a barren

[1] "Principles of Geology," vol. i. p. 336 (11th edition).

[2] Described and figured by E. Whymper, "Scrambles Amongst the Alps," p. 431. These appear to have been carved from a moraine. All but one were without capstones, and some were quite 20 yards high.

[3] J. Ball, "Alpine Guide: Eastern Alps," p. 88.

waste. The water, of course, works its way underground, making tunnels and caves. The former have often been intersected by glens, and may be seen in the cliffs. I noticed some interesting cases in the district round the Dachstein, where the water had cut down through strata some of which had yielded more easily than others, so the section of its channel took the form of a prolonged dumb-bell. But when its downward progress is checked by coming upon a comparatively unyielding floor, it works out a cave. Instances of these are common in every limestone district. Often the stream which has made them has disappeared, having at last forced its way through the obstacle to a lower level; but occasionally it, or a tributary, may be encountered, as in the Grotte des Fées, above St. Maurice, or the river comes to the light of day, sometimes forming a cascade in the face of a cliff, as it does in at least three places near Trafoi, at the base of the Ortler, sometimes breaking out from a rocky slope, as in the well-known Siebenbrunnen, above Lenk in the Simmenthal.[1] The Adelsberg caves, on the route between Marburg and Trieste, are the most remarkable example. But as these lie rather beyond the strict limit of the Alps we must pass them by without entering into details, only remarking that here a river (the Poik) burrows underground for a distance of more than two miles, finally returning, augmented by tributaries, to the light of day under a new name.[2] Caves and

[1] When I saw them they were no longer seven; now, according to Baedeker, there is only one.

[2] Instances of all that we have been describing can, of course, be found in some limestone districts in our own country.

subterranean water-courses, as might be expected, are also common in the Jura; but they are rare and small in the crystalline regions of the Alps. The noted Baume des Vaudois, or Balme-Chapelu, among the crags of the Pelvoux, above the Val Louise, must, however, be of considerable size, for in it a large number of the Vaudois sought refuge from their persecutors, and were at last ruthlessly massacred; those within its recesses being stifled by piling brushwood against the entrance and setting it alight. According to tradition the victims numbered three thousand; but that more probably applies to the whole Vaudois population of the valley, and Joanne[1] states that the present aspect of the cave cannot be reconciled with the story, so we may hope it has been exaggerated.

But the most interesting caves in the Alpine region are those called Glacières, which, as the name implies, are ice-houses, but natural instead of artificial. They are not, however, restricted to the Alps, for seven at least are dotted about the Jura; there is one near Die in the south of Dauphiné, and a few in other parts of the world.[2] In the Alps I have myself seen six, if one in the Val d'Hérens be counted, which is hardly worthy of the name, and as they are but seldom visited by travellers I will describe one of

[1] "Itinéraire du Dauphiné," 2^me partie p. 190 (1863). I was not able to visit the cave when on the Pelvoux.

[2] Almost all those in the Alps were described, after personal examination, by G. F. Browne (now Bishop of Bristol) in his pleasantly written book, "Ice Caves of France and Switzerland" (1865), with notes on more distant examples, and a discussion of their physical history. Another subsequently visited is described by him in "Off the Mill" (1895), p. 90.

the most accessible. This is on the north side of the Lake of Thun, in the cliffs overhanging the Justisthal, at a height of about 5,840 feet above sea-level. The entrance is a fine natural doorway, about eight yards high and eleven wide, which commands a splendid view of the Jungfrau. For a short distance the cave runs nearly at the same level at right angles to the cliff-face; then, after a slight southerly deflection, it curves rapidly round towards the north, and the floor begins to descend. The roof maintains nearly the same level, so that the height of the cave increases considerably. Huge blocks, evidently fallen from above, are piled upon the floor. Presently we find small stalagmitic incrustations of ice on these blocks, and a little farther on, where the light of day has faded away, this occurs in large quantities. "It streams down the rocky walls in transparent sheets, and hangs in clustering stalactites from the roof. Beneath these stalagmitic masses rise up from the floor, which in one case had united with the pendants above, so as to form a column of purest ice a foot or so in diameter. Before reaching them, ice appears more and more frequently, not only on, but among the débris scattered on the ground, till at last it occupies all the floor of the cavern. Its surface is tolerably level, shelving slightly, on the whole, towards the left-hand side . . . and rising occasionally into a low undulation or protuberance. Water lay here and there in shallow pools, and the whole surface was exceedingly slippery and generally damp." The ice exhibited a peculiar prismatic structure, which we must leave for the moment. "Passing on, we came to a break in the level floor of the cave, the whole mass of ice suddenly shelving down at a tolerably steep inclination, and apparently plunging into the bowels of the earth." This, however, is illusory; the slope, partly of ice, partly of screes, is not a long one, and leads to a second level floor, with surroundings like the one already described, except that here the prismatic structure of the ice was less distinct and sometimes wanting. "The cave does not end gradually by narrowing into a fissure, but terminates almost abruptly, more like an incomplete tunnel, the roof close to the end being perhaps a dozen feet from the stone-strewn floor." [1]

These glacières suggest two questions not easily answered, namely, What is their origin? and what the cause of the prismatic structure? Of the former several explanations have been offered, which are discussed in my friend's volume. Account must be taken of the following facts: the ice is always well below the entrance of the cave; the latter is protected from radiation; it is also so far shielded from the wind that warm air cannot have ready access, though during winter storms snow may be driven inside. On a summer's day the temperature is very near the freezing-point, usually a degree or so above, which accounts for the wet surface of the ice. Probably it often falls slightly below that during the night, for these caves commonly occur between 4,000 and 6,000 feet above sea-level, while for over six months in the year there would be a steady frost, and in some of them a considerable

[1] I visited it on July 8, 1870, and this account is condensed from one contributed to a College magazine, called *The Eagle*, vol. vii. p. 129.

incursion of snow.[1] Thus we both look upon them as natural ice-houses, which view, as we afterwards found, had already been expressed by Deluc. Their comparative rarity is probably due to the fact that as they are in most cases in zones where the mean temperature rather exceeds 32°, they can only exist under specially favourable circumstances.

This also we believe to be the cause of the prismatic structure which existed in every one of the thirteen visited by my friend, though the prisms were not constant in size, ranging from about half an inch to rather more than two inches in diameter, and not often exceeding two or three inches in length. They are at right angles to the surface, whether that be curved or flat, and may be seen occasionally, after a slow thaw has begun, in the ice of ponds in England. Their coherence is so imperfect that a cake of ice a couple of inches thick can easily be broken up with the fingers and the prisms separated. They are, I believe, a result of contraction, like the columnar structure in starch, or in the sandstone lining of furnaces, or, on a larger scale, in basalt and other volcanic rocks. How this takes place in a substance with the peculiar properties of ice is not easy to understand, but the structure, at any rate in the open air, only appears during a slow thaw, when the ice has been kept for a considerable time very nearly at its melting-point.[2]

[1] Both air and earth mean temperature at the Schafloch must be very near the freezing point—not more than 33° according to my estimate. In "Ice Caves" it is given as 33·88° (p. 310), which, as it is calculated from Geneva, is probably a little too high. Two caves in the Jura work out at 38·55° and 40·32.°

[2] For a fuller discussion on the subject, see "Ice Caves, chap. xviii., and "Alpine Regions," chap. iv.

Mineral springs must receive a brief notice before we quit subterranean topics. These, in the Alps, are large in number [1] and diverse in nature. Sometimes the waters are used for drinking, at others for bathing, often for both purposes. Most of them are at least slightly tepid; a few are very warm. Some contain little more than carbonic acid; others carbonates, especially of iron and lime; many are alkaline, and several saline. The springs at Ceresole, on the southern side of the Graians, are so charged with gas that when an uncorked bottle, recently filled, is brought to table, the water effervesces in the glass. The St. Moritz waters also are slightly effervescent; they contain salts of alkalies and iron. Those of Bormio, Bad Gastein, Brides-les-Bains, and Brags are more or less alkaline; at Allevard and Leuk they are chiefly saline; at Courmayeur, St. Vincent, Sta. Catharina, and Monêtier chalybeate; at Uriage, Ratzes, and Stachelberg chiefly sulphurous; while one or two, quite as noted, like Pré St. Didier and Pfäfers, are little more than pure hot water. At the baths of Leuk, which have been repeatedly described, the springs vary in temperature from about 90° to 120°, and the patients lead an amphibious life, passing sometimes as much as eight hours daily in the bath. Floating tables enable them to read books and play games, and, as a complete costume is worn, both sexes are together, and friends gossip with them from the galleries. At Monêtier one of the two springs issues from the ground at a temperature of nearly 108°, and is so rich in iron that the pebbles in the

[1] Switzerland alone was said in 1868 ("Alpine Regions," p. 106) to have 246 bathing establishments.

stream carrying off the waste water are thickly coated with rust. At Ratzes and Stachelberg the baths have a lid, to protect the patient from the fumes, his head and shoulders protruding from an aperture, and at the latter place the water is the colour of brimstone, and its odour lingers for some hours. But Pfäfers is the most romantic, and in another respect not the least remarkable of the Alpine springs. The source is in the gorge of the Tamina, which is very narrow, and at least 300 feet in depth. After passing through a bath-house at the entrance, we follow a wooden platform, built a few yards above the torrent. "Here and there the rocks appear to close overhead, and you grope your way in a twilight gloom; then they part again, and show a glimpse of fringing trees and blades of grass, glittering in the sunlight, while perhaps one stray beam struggles through the shade, and for a moment gleams upon the gloomy torrent. Presently a dense mist is seen rising from the waters. It is the reek of the hot springs, wildly beautiful when lit up by the sunbeams."[1] The temperature of the principal spring is about 99°. The waters are limpid, and contain only a very small quantity of chloride of sodium and magnesium, yet they are highly beneficial in certain gastric and rheumatic disorders; so much so that, when re-discovered by a hunter in 1240,[2] for many years afterwards patients were lowered from above, left there with the poorest of shelters[3] till they had completed their course, and were hauled up

[1] "Alpine Regions," p. 108.

[2] They were known in the eleventh century, but owing to the danger of access had been disused and forgotten.

[3] Built in 1242 by the Benedictines of Pfäfers Abbey (Baedeker).

again actually the better for the treatment. Now there is not only a rather large bath-house at the entrance, but the water is carried down to Ragatz, in the Rhine valley, with little loss of heat, though quite two and a half miles away, and there the invalid can find ample and, if desired, luxurious accommodation.

Springs of strong brine, often associated with rock-salt, occur in some districts. Those of Moûtiers Tarentaise have been known since Roman times, and are still worked. The water contains some carbonic acid and sulphuretted hydrogen, besides a little sulphate of soda and lime, and magnesium as well as sodium chloride. But of the last the amount is not quite 2 per cent., so a cheap and ingenious process is used for concentrating the brine, which is described at full length by Bakewell.[1] It is conducted from the springs to the Salines, where the process is carried out, and there allowed to trickle down over piles of faggots or lines of cord. Some water evaporates, and the residue is again pumped up, this being repeated till the strength of the brine is greatly increased, when it is boiled in the usual way. Salt, of course, is deposited on the faggots and cords, which is collected at suitable intervals.[2] Rock-salt also is obtained in several parts of the Alps; for instance, close to Bex in the Rhone valley, by the Lake of Hallstadt, at Hallein near Ischl, and near Berchtesgaden. At the last, in 1872, the visitor put on a suit of protective vestments, with a leathern

[1] "Travels in the Tarentaise," vol. i. chap. vi.

[2] That method was followed when I visited the place in 1862, and is probably still in use.

flap antithetical to an apron. Then, after a journey through a tunnel lined with masonry, he came to the live rock, a dark clay or shale, nodular in structure, and traversed by thin veins of salt. Sometimes, however, he passed through or under harder strata, mounting an occasional flight of steps, till he entered a huge chamber, doubtless artificial, with a flat roof, which was filled with brine up to just below his feet. In the middle a fountain played, and a row of lights along one side was reflected in the water. Across that he was rowed in a boat, and on landing at the other side presently seated himself on a slide, constructed of smooth poles, which sloped down into the darkness, and indicated the use of the reversed aprons. Letting himself go, he plunged downwards, and a short walk, when that trial to the nerves was over, brought him into a large excavation, where rock-salt was quarried. More passages followed, and another brine spring, till at last he mounted a sort of wooden horse, which brought him back to the daylight and freedom from his outer casing.

Other minerals of commercial value occur locally in the Alps. Gold is found in small quantities, especially near Monte Rosa, the most productive spot being at Pestarena in the Val Anzasca, where it has been worked since Roman times.[1] It is embedded in pyrite, like that in the "banket" of the Transvaal, and, as is the case there, the grains are often so minute as to be indistinguishable by the eye. Silver is worked near Auronzo and Primiero in the Italian Tyrol and La Grave in Dauphiné. Mercury, chiefly

[1] Described by De Saussure, "Voyages," §2132, and King, "Italian Valleys of the Alps," chap. xv.

cinnabar, is obtained at Idria in Carniola, but occurs rarely in the Alps; nickel mines exist at La Balma in the Val Sesia, Migiandone near the Simplon road, and not far from Grimentz in the Val d'Anniviers. Lead mines are not infrequent; copper is found in the Val Pelline, the Val d'Aoste, especially in the tributary Val St. Marcel,[1] the Val Sesia, and several other localities. The most noted iron mines are those in the Val de Cogne, which have been worked, off and on, since Roman times. The ore, which is obtained in two of the upper glens, is the magnetic oxide. The smaller and more accessible of the mines, called the Filon Larsine, is some little height up the steep left bank of the Vallon de Grauson, and is worked in several openings. But the other mine, the Filon Licone, is a much larger affair.[2] It is on a mountain slope at a height of 7,667 feet above sea-level and can be reached in about two and a half hours' walking from the village of Cogne. The ore is associated in both places with a mass of serpentine, which is intrusive in calc-mica schist, and it passes quickly, but by almost insensible gradations, into the former rock. One authority gives the length of the mass as a little under 500 feet and its maximum thickness as 82 to 98 feet; but the whole extent is not generally exposed. It is worked as an open quarry on the hillside, the ore being extraordinarily pure. For reasons given in the paper to which I have referred I have no doubt that it is really a huge inclusion, and that the olivine rock (which has been converted into serpentine), while it was being forced

[1] Here also manganese is obtained.

[2] Condensed from a paper by the author, *Quart. Jour. Geol. Soc.*, vol. lix. (1903), p. 55.

from beneath into a higher position in the earth's crust, encountered and tore off a mass (probably barely solid) of magnetite, which it carried up. At the margin of the two semi-molten substances the component minerals would be more or less mixed together so as to form the passage zone which has been already mentioned.[1]

Among minerals which generally occur in smaller quantities but are greater attractions to the collector, asbestos is not uncommon, and in one case at least, on the way from Chiesa in the Val Malenco to the Canciano Pass, is in a mass large enough to be worked. Near the former village a potstone, some kind of massive chlorite, is obtained, which is used for cooking vessels and other purposes where endurance of heat is important. Near Zinal a talc-schist is quarried and the slabs are employed in constructing stoves; varieties of both materials are obtained in a few other localities. Fairly good crystals of one or another species of chlorite occur in several places, Zermatt being one of them. Tremolite, a white hornblende, is rather abundant in the crystalline dolomite which forms the crest of the range south-east of the Lago di Tremorgio; actinolite, another form of that mineral, also elongated in shape, but green in colour, is abundant in a band that crosses the Val Canaria on the south side of the St. Gotthard; glaucophane, a rather rare violet-blue hornblende, is found in several places; for instance, on the Viso, in

[1] *I.e.*, the rock called Cumberlandite. As the specific gravity of magnetite is much higher than that of olivine it should have been at a lower depth than the latter, but the great folding the Alps have undergone may account for anomalies.

the Saas and Zermatt districts, in the Val d'Aoste, on the southern side of which, above St. Marcel, it is so abundant that many of the blocks paving the mule-track or forming its rough walls are a glaucophane-eclogite. In the upper part of the tributary glen, which joins the Dora Baltea valley at this village and is named from it, piedmontite is obtained, the manganese-bearing epidote, a rare and richly-coloured mineral. Red garnets (almandite) are often abundant, but are of no value to the gem-cutter. Specimens not larger than currants in a cake and as close together characterise some mica-schists and gneisses, but they are occasionally as big as cherries; for instance, in a zone extending eastward from near the forts on the south side of the St. Gotthard Pass towards the Val Piora. In the Val Canaria I found one fully an inch in diameter; but they run quite as large as that near Premia, in the Val Formazza.[1] Black garnets, about the size of large peas, probably dirty almandites, are also very common at intervals in a dark schist, which may be traced for many miles through and beyond the Lepontine Alps. Small but well-formed crystals of a pale-red garnet (essonite) are found with a chlorite and diopside (an almost colourless augite) at Ala, in Piedmont. Fairly good specimens of kyanite and staurolite occur separately on the northern flank of the Lago Ritom, and finer specimens of the one are obtained, together with the other, high up the Pizzo Forno, near the Campolungo Pass.[2] Pretty well

[1] I got a specimen there so long ago as 1860. That was from the old mule-track. The rock, as I found to my regret in 1907, is not seen from the new carriage-road.

[2] The Binnenthal is rich in rare minerals, which, however, are generally so inconspicuous as to be noticed only by experts.

crystallized tourmalines, andalusites, and zoisites are obtained at one or two places in the Tyrol, and the first reaches a fair size in the crags of Monte Rosa above the Gorner Glacier. Rather good crystals of albite felspar come from the neighbourhood of the St. Gotthard Pass, and those of orthoclase from the granite near Baveno have given a name to a particular form of twin. Quartz crystals are common in many of the crystalline regions. Those from the Val Venéon in the Dauphiné Alps take a singular shape in consequence of the unequal development of their faces; in other places specimens are obtained remarkable for their size. The Natural History Museum at Bern contains several specimens of "smoky" quartz from a fissure in the cliffs flanking the Tiefen Glacier (on the north side of the Urserenthal), which was accidentally discovered in 1868. The crystals removed from it are said to have weighed 12½ tons.[1] In a group of seven giants the longest, Der König, is just over 2 feet 10 inches and is 3 feet 3 inches in girth, while another, Der Dicke, is slightly more than 7 inches shorter, but is stouter by 4 inches.

[1] Baedeker, "Switzerland," ii., Route 35.

CHAPTER IX

AVALANCHES AND FLOODS

BEFORE quitting the subject of denudation and transport we must describe a few agents which are local and rather catastrophic in character. Among these, avalanches[1] are perhaps the most notable, of which there are several kinds, some consisting of snow or ice, others of rock. At any time of the year, after a heavy fall of snow upon the higher slopes of a mountain, this may slip off the underlying surface when it is hard frozen or is steep and smooth turf. Frequently also at the coming of spring large masses of half-solid snow scale away from the mountain-side and slide down to the valley. The first is commoner in the winter, but is occasionally a danger in summer after bad weather, and in the German-speaking districts is called, from the incoherency of its material, *Staub-lauine* (dust avalanche). The other consists of more compact snow and bears the name *Grund-lauine* (ground avalanche). Our house roofs often afford instances of either on a small scale, the one occurring

[1] Avalanche is the French name, Lauine the German, valanga the Italian, and lavina the Romansch. It seems to be connected with the Latin word *labi* (to glide), and appears in a document about Canton Schwyz, dated 1302, under the form lowinæ (W. A. B. Coolidge, "The Alps in Nature and History," p. 30).

soon after a snowfall, the other when a thaw sets in after a long frost. Both kinds of avalanche may be destructive to property or life, but the latter are generally the more formidable. They sweep broad paths through the forest-clad slopes, laying low and even tearing up the trees and carrying downwards soil and boulders; may block roads, crush cottages, overwhelm cattle, entomb human beings. In sunless ravines the fallen snow often lingers till late in the summer, and occasionally may only be removed by one of exceptional warmth. In some cases the amount brought down is very large. On March 27, 1907, I saw, on the left bank of the Reuss, about half a league above Altdorf, an avalanche lying like a glacier on the slope, one lobe of which almost reached the river, and though diminished, it was still large when I returned on May 2nd. The dust avalanches are more dangerous to the winter traveller. In walking up a mountain valley we not unfrequently see by the side of the path a little cross to commemorate some peasant who has found death and temporary burial beneath the falling snow, and now that winter expeditions on snowshoes or ski attract so many visitors to the Alps, the tale of those who shall return no more is annually increasing. At the beginning of December, 1720, General Macdonald's troops lost heavily in crossing the Splügen Pass, about a hundred men being swept away by avalanches in the Gorge of the Cardenell alone. It is said that in the year 1500 six hundred persons were overwhelmed by one in crossing the Great St. Bernard, and half that number in 1624, by another from Monte Cassedra, in Canton Ticino; but in less distant times one of the best authenticated falls occurred on February 18, 1720, at Obergestelen, about two leagues from the end of the Rhone Glacier. During the night an avalanche came down upon the village and destroyed 120 cottages, 400 head of cattle, and 88 persons. The last were entombed in a large pit in the churchyard, over which this epitaph was inscribed: "*Gott, welche Trauer! acht und achtzig in einem Grab!*"[1] Pine forests, if large enough, are useful defences against avalanches, and in certain positions are maintained for this purpose; and in others strong, wedge-like defences have been constructed above a village to divert the snow into a harmless direction. Protective galleries also are constructed in dangerous parts of the great high-roads; so that although these winter missiles of the mountains occasionally exact their toll of human life, the losses now bear a much smaller proportion to the number of travellers.

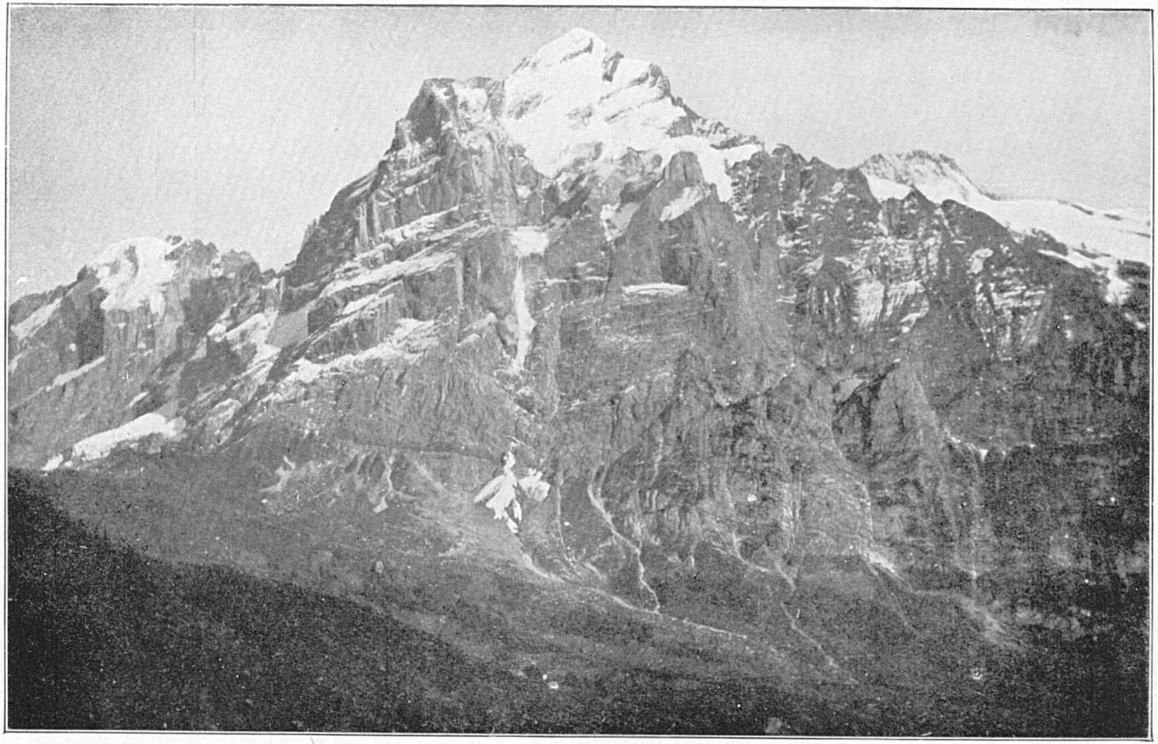
Ice avalanches are frequent, especially in summer. On a small scale these are formed by the fall of a sérac, the effects of which are, of course, very local; on a larger they occur when the ice breaks off on arriving at the edge of a cliff. Occasionally these sweep slopes which must be traversed in ascending a high peak or pass, and are thus dangerous to mountaineers, but the ordinary traveller is quite out of the range of fire. The ice cascades from the northern cliffs of the Jungfrau are among the attractions of the Wengern Alp. About a mile away they seem like a smaller but fuller Staubbach, which leaps suddenly down a cliff from an unnoticed gorge, and almost as quickly dies away. Occasionally, probably in consequence of a large mass

[1] The Author, "The Alpine Regions," p. 124.

falling on a rock ledge, and shattering like a burst bombshell, they are "like a downward smoke"; not indeed "slow dropping veils of thinnest lawn," but resembling a puff of steam shot downwards instead of upwards from some gigantic locomotive. The late Sir F. Galton in 1862 discovered a way by which one of the more frequented channels could be approached in safety. Sheltered under an overhanging slab of rock he watched their passage. One of the largest "gave notice of its coming by a prodigious roar, and the appearance of an exceedingly menacing cloud of snow-dust that was shot out far above my head, . . . the hurtling of the ice-balls in the depths of the ravine, and the crash of the huge hailstorm that issued at its foot, were almost frightful. The storm was remarkable for the irregularities of its outbursts." [1]

Occasionally, however, though happily but seldom, a considerable portion of a glacier comes down at once. The Bies Glacier, on the eastern face of the Weisshorn, did this in 1636, and destroyed a large part of the village of Randa, killing thirty-six persons. Another large mass again broke away on December 27, 1818, when blocks of ice were hurled half a league up the opposite slopes of the valley. According to an official document, the village was not struck by the fall of the glacier, but the wind thus raised was very destructive. "The point of the steeple was carried away: houses were levelled with the ground, and the beams of which they had been built flung to a great distance in the forest." Many cottages and outhouses were either destroyed or much damaged, but happily only two

[1] *Alpine Journal*, vol. i. p. 186.



25. AVALANCHE ON THE WETTERHORN.

(*From a photograph by Mrs. Aubrey Le Blond.*)

To face p. 222.

persons were killed. The débris of stone, ice, and snow, forming a mass of 360,000,000 cubic feet, covered all the cultivated land below the village (it is about 250 feet above the Visp) for a space of about 2,400 feet long and 1,000 feet wide.[1] The most recent serious disaster of this kind was caused by the Altels on September 11, 1895, though an earlier one in August, 1872, is on record.[2] From the path of the Gemmi that mountain resembled a great pyramid of limestone, covered with ice from a height of about 9,800 feet to its summit (11,929 feet), and broken in one place at a lower level by a slight plateau. Some chalets were situated at the foot, and half a league nearer the top of the pass is the well-known Schwarenbach inn. For some days the temperature had been high, a Föhn wind blowing, while the summit of the mountain was wrapped in clouds. About 5 o'clock in the morning a loud roar was heard, accompanied by a violent blast of wind. "The huge mass of ice forming the lower end of the glacier had broken away, rushed down the mountain side, leapt from the plateau into the valley, and like an immense wave had swept over the alp, up the Uschinen Grat (opposite), as if up a 1,500 feet sea-wall, and even sent its ice-foam over this into the distant Uschinen-thal. . . . The cow-chalets and huts of Spitalmatten had disappeared, smashed into splinters and blown over the alp"; the inhabitants, six in number at the time, were killed, besides 158 cows, some by the wind, some by the direct fall of the avalanche. Many of them were carried from nearly 550 to well over 1,000 yards, and their bodies left

[1] Venetz, *Conservateur Suisse*, vol. x. p. 205.

[2] "Central Alps," part i. p. 46.

from 800 to 1,150 feet above the place from which they had been blown. The trees of a pine wood were laid flat in parallel rows, like swathes of corn. According to Professor Heim's estimate, "the mass of ice that fell (through a vertical height of 4,700 feet, and a horizontal distance of less than 1¾ miles) was 4,500,000 cubic metres." [1]

On a still grander scale, and yet more destructive, are rock avalanches or berg-falls. Occasionally they make some compensation, for it was to a mass which fell from Monte Pizzo, in 1771, that we owe one of the most beautiful scenes in the Dolomites—the Lago d'Alleghe, in which are reflected the grand cliffs of Monte Civetta. But as a rule only ruin marks their track. A few out of the many instances are all that we can notice. On September 25, 1714, a great mass which fell from the higher crags of the Diablerets buried fifty-five chalets, with many head of cattle and sixteen men. Of the latter, one only survived, and his escape was marvellous. His chalet was built against a crag, and a large block fell in such a way as to protect it. Thus he was buried alive. Fortunately a streamlet made its way through the débris and trickled into the chalet. Supported by this and by his store of cheese, he lived three months, labouring incessantly to escape. In this he succeeded shortly before Christmas, and made his way home to the village of Avent. His friends had mourned for him as dead, so every door was shut against him, and the priest was summoned to exorcise the supposed spectre. Not till he came could the unfortunate man persuade them that he was alive. Better known, and more

[1] C. Slater, *Alpine Journal*, vol. xviii. p. 431.

destructive, was the fall of the Rossberg, the ruins of which are piled on either side of the railway from Lucerne to Brunnen, near Goldau station. The mountain consists of thick beds of *nagelfluhe*, a hard pudding-stone, resting on less coherent strata, and sloping towards the valley. The catastrophe happened after a very wet summer, on September 27, 1806. For two days rain had fallen incessantly; then new cracks appeared on the flank of the Rossberg; groaning sounds were heard; the ground at the base of the mountain seemed to be pressed down from above. At last, about five o'clock in the afternoon, a large chasm opened out on the side of the Rossberg, and a mass, about three miles long, 350 yards wide, and 33 yards thick, glided down into the valley, breaking up as it went into fragments, large and small. "In five minutes one of the most fertile valleys in Switzerland was changed into a stony desert. Three whole villages and part of a fourth, 6 churches, 120 houses, 200 stables or chalets, 225 head of cattle, and 111 arpents[1] of land were buried under the ruins of the Rossberg."[2] The dead numbered 484. Seven among them were visitors. They were about a furlong in advance of four others, the rest of their party. These "were attracted by something strange in the appearance of the Rossberg, and took out their telescopes to see what was the matter. Suddenly, a volley of stones hurtled over their heads, a cloud of dust filled the valley, and a fearful crash was heard. They fled for their lives. When tranquillity was somewhat restored they returned to seek their friends, but they and Goldau were buried

[1] An arpent is 40,000 square feet (French).

[2] "The Alpine Regions," p. 129.

beneath a hundred feet of débris. Of that village nothing but the church bell was ever found."

But an earlier catastrophe in quite another part of the Alps was yet more terribly disastrous. In the beginning of the seventeenth century there was a town named Plurs in the valley of the Maira, about three miles above Chiavenna, which, as a convenient entrepôt of German and Italian merchants, was prospering greatly. But on August 30, 1618, a huge mass of rock from Monte Conto crashed down upon the town, which was practically effaced. A solitary campanile, rising above a wilderness of shattered rock and tangled vegetation, marks the spot round which about 1,500 persons perished. The landslip of Elm, a pleasant village in the Sernfthal, though less destructive than either of these, is recent enough to be remembered by the older generation of travellers in Switzerland. It occurred in the afternoon of September 11, 1881. For some days before there had been rumblings and quakings in the flanks of the Tschingelberg, a mountain to the south-east of the village, so that the cantonal authorities had forbidden the cutting of wood and recommended the stopping of slate quarrying in the more exposed spots. But suddenly "the land, rocks, and woods below a rugged, rocky summit gave way, and fell a distance of 1,500 to 2,000 feet. . . . A few houses only were destroyed by this first fall, and the villagers of the neighbouring hamlets were hastening to the aid of the unfortunate people when two new and more terrible falls took place and overwhelmed all—rescuers and sufferers." The entire hamlet and all the quarry buildings of Unterthal were destroyed, together with a valuable stock of slates, and 115 lives were lost. Professor

Heim estimated the weight of the fallen mass, which covers an area of about a square kilometre (1,094 yards square), to be 20,000,000 tons.[1]

In 1898 serious damage, attended with some loss of life, was done to the western end of Airolo on the St. Gotthard route by a fall of rock from a mountain to the north, which threatened also to bury the railway. A recurrence of the catastrophe has been averted, as it is hoped, by the construction of defences: some high up on the slope, others, like massive fortifications, just above the town and entrance of the tunnel.

Mud avalanches are altogether more local and pass sometimes insensibly into floods. These, so far as one can infer, were commoner and on a larger scale in times immediately succeeding the Ice Age than at the present day. The earth-pillars of the Finsterbach and Katzenbach, near Botzen, at the entrance of the Saasthal, and at Useigne in the Val d'Hérens, not to mention others, are carved, as we have said, not from moraines, but from material which, though no doubt often in large part morainic, has been transported some distance by water. A good example of such a deposit, in a position where it could not have been placed by a glacier, may be seen near Huteck, in the Saasthal.[2] In the Himalayas, where disintegration seems to be now more rapid than in the Alps, these mud streams are rather common. They have been noticed of late years by Colonel Godwin-Austen, Dr. and Mrs. Bullock Workman, and Sir Martin Conway, who saw two issue from a gully near the Hispar

[1] *Alpine Journal*, vol. x. p. 422.

[2] The Author, *Geological Magazine*, 1902, p. 8.

Glacier—one just before, the other just after, his party crossed it. This is his description:[1] "It was a horrid sight. The weight of the mud rolled masses of rock down the gully, turning them over and over like so many pebbles, and they dammed back the muddy torrent and kept it moving slowly but with accumulating volume. Each of the big rocks that formed the vanguard of this avalanche weighed many tons: the largest were about ten-foot cubes. The stuff that followed them filled the *nala* to a width of about forty and a depth of about fifteen feet." Finally the material spread out as a fan on the bed of the valley below.

Something of this kind must have caused the temporary lake in the valley of the Visp. On June 12, 1907, a mass of stony mud swept across its bed from a ravine on the right bank. It completely blocked the course of the river some two or three miles above that town and formed a lake, submerging the railway for a few hundred yards, so that it became necessary to construct a new track above the level of the water. On July 24th of that year telegraph posts, trees, and bushes were standing out of the water, the greater part of which must have been not less than 8 feet deep. At the lower end the Visp, which had been forced against the left bank of the valley, was rushing through a channel which it had already cut in the débris, and may have by this time restored the valley above to its original state. This, however, was a comparatively small matter. A blockage with much more serious consequences occurred in the valley of the Romanche. Near Bourg d'Oisans, the almost simultaneous junction of the Vénéon and the Olle

[1] "Climbing in the Himalayas," p. 323.

with the main river causes a considerable enlargement of the valley, which only a little way lower down becomes, at the Combe de Gavet, extremely narrow. This was completely blocked in the twelfth century by a landslip from a mountain at its northern portal which converted the plain into a lake, in some places 30 feet in depth. So it remained for many years, "till, on the night of September 14, 1219, the dam suddenly burst, and the accumulated waters rushed down the valley, sweeping everything before them. Many villages were destroyed, with their inhabitants, and at Grenoble itself numbers were carried off by the flood."[1] In the year 1512 a similar lake was formed in the Val Blenio, which was 12,000 paces round, and so deep that only the tops of the church steeples stood above the water. This lasted for two years and then burst, spreading ruin over the whole valley between it and the Lago Maggiore, and bringing death to more than six hundred persons.

Glaciers also sometimes dam up streams, till the accumulated waters force an opening through the ice and flood the valley below. The Märjelen See is known to almost every one who has visited the Eggischhorn. Here the Great Aletsch Glacier has blocked the mouth of a small lateral valley and converted it into a lake. This, at the lower end, is nearly 100 feet in its deepest part, and the ice formerly rose above it in steep cliffs to about 60 feet. Great blocks detached from them float about in the water. This, however, at intervals of about seven years, forced its way beneath the glacier, and rushed down to the valley of the Rhone, with the result of burying

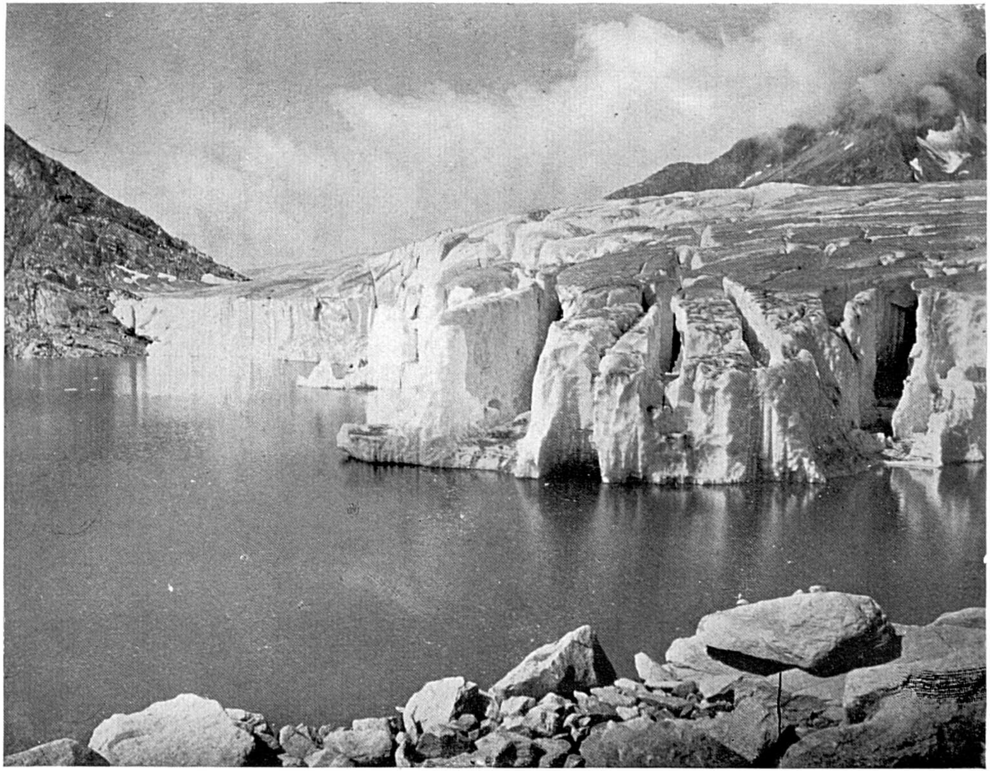
[1] The Author, "Alpine Regions," p. 134.

some acres of fertile valley-land beneath stony mud.[1] The lake, when first I saw it in the summer of 1858, was in all its beauty; but when I returned next day it was greatly changed; most of the water had disappeared and was replaced by a bed of dark mud, on which many icebergs, some from 30 to 40 feet high, and longer but rather narrower, were stranded; while about 60 feet of almost smooth blue ice had been added to the cliff.[2]

A far more tragic chapter in mountain history was caused by the bursting of a subglacial lake on the flank of Mont Blanc, above the Baths of St. Gervais. "Owing to the stoppage of the subglacial drainage, in some manner never precisely ascertained, a lake was formed under the Tête Rousse Glacier, in which an enormous body of water was pent up at a spot 10,000 feet above the sea-level. Between one and two o'clock on the night of July 12, 1892, the ice that held up the lake gave way. The water swept in a torrent of tremendous force over the Désert de Pierre Ronde, gathering up thousands of tons of rocks and stones in its course . . . it destroyed half the village of Bionnay on the high road between Contamines and St. Gervais, joined the main river of the Bon Nant; following its bed . . . it hurled its seething flood of water, timber, stones, and mud upon the solid buildings of the establishment and crushed them into fragments; then crossing the Chamonix road, it spread itself out in the form of a hideous fan over the valley of the Arve, destroying part of the

[1] *Alpine Journal*, vol. vi. p. 100; vol. ix. p. 444.

[2] The shrinkage of the ice, and the lowering of the lake by cutting a channel at its upper end, have now diminished its beauty.



From a pho'o by] [*Mr. J. J. Lister. F.R.S.*

26. THE MÄRJELEN SEE.

To face p. 230.

village of Le Fayet on its way." [1] The exact number of the victims could not be ascertained, but it exceeded a hundred and fifty.

The disastrous flood in the valley of the Dranse was also caused by a glacier. On the eastern side of the Val de Bagnes, the Giétroz Glacier descends from the snowy range separating it from the Val d'Hérens. In the later part of 1817 this glacier not only reached the main valley,[2] but also made such a complete barrier that a lake was formed nearly two miles long, four hundred feet in width, and about half that depth. "It was well known what the result of this would be, for in 1595 a similar barrier had been formed, which had at last given way and devastated the valley for miles below." The only chance, therefore, was to "tap" the lake, which was done next year under the direction of M. Venetz, an eminent Swiss engineer. "A band of labourers, working day and night, cut a tunnel 600 feet long through the glacier, which was completed just as the water reached the level of its opening. The current quickly deepened and enlarged this, and between the 13th and 16th of June about two-fifths of the water was drawn off. But the cutting thus formed so much weakened the barrier that on the latter day, at half-past four in the afternoon, it suddenly gave way, and the remaining contents of the lake swept down the valley. . . . It is said to have

[1] C. E. Mathews, "The Annals of Mont Blanc," p. 246.

[2] Some accounts state that the obstacle was formed by ice which had broken off the actual glacier and frozen into a solid mass. When I passed the place in 1874 and 1875 the ice had retreated so far that one could not ascertain what had happened.

issued from the defile of Lourtier (a few miles below the glacier), like a moving wall or mound, a hundred yards high, the head of the column of water being entirely masked by the confused mass of mud, stones, beams, and trunks of trees which it swept along." [1] It poured through Martigny into the Rhone, destroying five hundred houses and cottages, with several bridges, and rendered a great quantity of land useless, at any rate for many years. Though the people in the valley below had been warned of the danger, fifty lives were lost.

Heavy rainstorms over the higher valleys also sometimes cause serious floods, but in the Alps these are not so disastrous as in the Pyrenees, or at any rate do not so often extend beyond their margin, because nearly every one of the larger rivers, sooner or later, passes through a lake, the level of which is but little raised by the swollen torrents. But, higher up the valleys, bridges are swept away, roads buried under torrents of mud, and fields overwhelmed with débris, after severe and long-continued storms, as I have seen on more than one occasion. The stream which flows through Vevey, harmless as it generally looks, once so overflowed its banks that the water was 9 feet deep in some of the streets, many houses and cellars were filled with mud, and several persons drowned.[2] After a long and violent thunderstorm at Locarno [3] "every

[1] "The Alpine Regions," p. 135. Fuller details are given in *Conservateur Suisse*, vol. ix. p. 365. Sir C. Lyell, who on August 9–11 of the same year visited the valley, gives a graphic description of the havoc ("Life and Letters," vol. i. chap. iv.).

[2] On July 5, 1726. *Conservateur Suisse*, vol. ix. p. 214.

[3] On September 2, 1556, *id.*, p. 431 ("Alpine Regions," p. 136).

rivulet was changed into a torrent: the stream which flowed through the town was so choked by uprooted trees and rocks that its waters poured over their banks and inundated the streets, almost burying them under mud and gravel. Many lives were lost and an immense quantity of property destroyed"

CHAPTER X

ALPINE METEOROLOGY

THE first connected series of meteorological observations at high altitudes in the Alps was undertaken by that great pioneer of scientific exploration, H. B. De Saussure, who encamped on the Col du Géant from July 3 to July 19, 1788.[1] He would have remained longer had it not been for his guides, who were tired of so monotonous and uncomfortable an existence. In the hut of the Col du Théodule meteorological work was continued for some months, about thirty years ago, and for the best part of a century observations have been made by the monks in the monastery of St. Bernard. On the Italian side of Monte Rosa huts for this purpose were erected, first at a height of 11,877 feet (the Gniffetti Hut), and, at a later date, the Regina Margherita Hut (14,961 feet), on the top of the Signal-Kuppe, or Punta Gnifetti.[2] Two observatories were constructed high up on Mont Blanc, one a little below the two snowy humps, called the Bosses du Dromadaire, at 14,320

[1] "Voyages," §§2029–2034.

[2] An account of elaborate observations made, with a most interesting discussion of the effects of diminished atmospheric pressures, has been given by Angelo Mosso in "Life of Man on the High Alps." Translation, 1898.

feet above the sea, the other on the summit of Mont Blanc itself. The first, a wooden hut, was completed in July, 1890, as well as a neighbouring refuge, at the expense of Mons. J. Vallot, a French mountaineer, who, in 1887, had spent three nights under canvas on the actual summit; the second was erected by the enthusiasm of Dr. J. Janssen, Director of the Observatory at Meudon. In both cases the difficulties of transporting the materials from Chamonix were very great, and in the latter there was the further one of obtaining a foundation. After vainly endeavouring to strike rock by making a tunnel about 50 feet below the summit and 170 feet in length, the building was finally erected on the snow, and completed by the end of 1894. Instruments were installed and observations carried on for some years, but the difficulties of keeping up communication and protecting the interior from the effects of the climate in winter proved too great, and before 1909 not only both were closed, but also the latter had been removed.[1] The Alps, evidently, are not suited for continuous observations at such elevated positions, and these will have to be sought in more southern latitudes. At Garstok, on the Tibetan slopes of the Himalayas, a place about 120 feet higher than the Regina Margherita Hut, an annual fair is held, and monasteries in Ladak, rather above that level, are inhabited throughout the year.

The barometer falls at an average rate of an inch for 1,132 feet of rise above the level of the sea, so that at the summit of Mont Blanc, 15,781 feet above this, it should stand just over sixteen inches. Here,

[1] Baedeker, "Switzerland" (1909), p. 347.

then, the pressure of the atmosphere is not much more than half the ordinary amount. That, obviously, must seriously affect respiration, circulation, and other vital functions. Thus the earlier accounts of mountain ascents, particularly of Mont Blanc, often dilate upon the sufferings of the climber. Breathlessness, palpitation, headache, nausea, even vomiting, and a sense of exhaustion and inability to move, necessitated frequent halts, till often he was at last dragged rather than walked up to the summit. Once there, however, the indisposition seemed speedily to vanish, and not to have recurred during the earlier part of the descent; the fact being that it was to a very large extent due to want of strength, or more often want of training, for a task undoubtedly laborious. When men, younger and accustomed to athletic exercises, began to ascend the higher peaks, little more was heard of ill-effects from the rarefaction of the air. Something, of course, depends on constitution. Certain persons suffer from difficulty of breathing and other inconveniences if they remain for any time in the ordinary mountain inns—that is, at heights of from 6,000 to 8,000 feet—while others feel only pleasurable sensations. Mountain air to myself has always been a tonic, and drawing the first breath as one stepped on a glacier was like a sip of champagne. Once only have I felt any symptoms of mountain-sickness, and that was while ascending the upper part of a pass not much over 9,000 feet in height. But there was a reason for this. It was at the end of my first visit to Dauphiné; for ten days we had been mostly living on poor fare—inferior bread, meat, and wine—and had spent three nights in hay-chalets, not without restless company, two others under a rock, and on the rest the beds were hardly conducive to sleep. We were all more or less "out of condition," and I happened on that morning to be the worst of the three. I have slept at 12,600 feet, and have often been at or above this level, twice over 15,000 feet, and have never noticed anything more than that, on approaching the latter elevation, I lost breath a little sooner than on an ordinary hillside. The well-known guides' precept, "*Plus doucement on monte, plus vite on arrive au sommet,*" recognises this fact, and I once had clear proof of it. We were ascending the Matterhorn after passing the night at the old hut but little more than 2,000 feet below the summit. This was still clear of clouds, but as the view would soon be spoiled there was obviously no time to lose. So, as my only companions were two first-rate guides, I broke the rule and found myself getting rather quickly out of breath, not exactly as one would do in running on the level down below, but as if the air did not properly inflate the lungs. More than once I had to call to the leader, "Stop an instant; I want to get a good breath," after which I went on for a while all right. We won the race, reaching the top while it was still clear, but the clouds were drifting over us before we left.

A more prolonged stay at an elevation such as that of Mont Blanc has, however, made itself felt even by guides and athletic climbers. In 1859 the late Professor Tyndall, with ten guides, spent about twenty hours, including a night, in a tent on the top of Mont Blanc. All were indisposed, some of them suffering more than himself. Mr. Whymper, during his ascents of the highest summits in the Ecuadorian Andes, ascertained by many careful observations that the rate of progress was considerably slower than at ordinary levels, and during his first ascent of Chimborazo both he and his two experienced guides, Jean Antoine and Louis Carrel, suffered severely from mountain-sickness at their first bivouac on Chimborazo, 16,664 feet above sea-level,[1] none of them having felt it on the Alps. They had arrived in perfectly good condition, though the native porters and the mules had already shown signs of great exhaustion, but an hour or so after arrival they were attacked. "We were feverish, had intense headache, and were unable to satisfy our desire for air except by breathing with open mouths. This naturally parched the throat and produced a craving for drink, which we were unable to satisfy—partly from the difficulty in obtaining it, and partly from trouble in swallowing it. When we got enough we could only sip, and not to save our lives could we have taken a quarter of a pint at a draught. Before a mouthful was down, we were obliged to breathe and gasp again, until our throats were as dry as ever. Besides having our normal rate of breathing largely accelerated, we found it impossible to sustain life without every now and then giving spasmodic gulps, just like fishes when taken out of water. Of course, there was no inclination to eat; but we wished to smoke, and found that our pipes almost refused to burn, for they, like ourselves, wanted oxygen."[2] The effects lasted about

[1] The barometer stood at 16·5 inches.

[2] "Travels Amongst the Great Andes of the Equator," chap. iii. The subject is also discussed in other parts of the book.

three days, and on the fourth they began to move upwards, without any recurrence of the symptoms, though their rate on the last day of the ascent "was deplorable. Nearly sixteen hours were occupied in ascending and descending 3,200 feet."[1] They felt no serious inconvenience during their second ascent, nor during a night spent on the summit of Cotopaxi (about 19,500 feet); and it was remarkable that, while they were suffering, an Englishman domiciled in Ecuador, who accompanied them as far as the bivouac, was comparatively well, though by no means a man of strong physique. Since that date yet higher ascents have been made and nights spent at greater altitudes—by Sir Martin Conway, Messrs. FitzGerald and Vines, Dr. and Mrs. Bullock Workman, Dr. Longstaff, and others—but it is generally agreed that exertion becomes more difficult as the height above sea-level increases. Experienced travellers in the Karakoram-Himalayas consider that the rarity of the air becomes disgreeably perceptible after getting above some 16,000 feet, which is a little higher than any point in the Alps. Sir Martin Conway[2] records two experiences which show that, even at a lower level, ill effects may be felt if the change be rather sudden. One was on the Oroya railway, which ascends from Lima to the crest of the Andes, "where it is rather higher than the summit of Mont Blanc," the journey taking about

[1] The barometer at the summit stood at 14·100 inches on the first occasion, and 14·028 (the lowest reading) on the second (pp. 70 and 325). These observations gave its height respectively 20,545 feet and 20,461 feet.

[2] "The Bolivian Andes," chap. iv.

nine hours. Till the train reached a level of about 10,000 feet the passengers were lively. Then the first symptoms were felt; "soon a great silence fell upon all. People crouched themselves into strange positions; they wrapped up their heads in shawls, or otherwise endeavoured to find relief for their unwonted sensations. . . . Before long uncanny sounds were heard from all parts of the train." Though not so seriously affected, he was conscious, after passing a height of 13,500 feet, of a slight dizziness and tension across the crown of the head, with some disturbance of the nerves, the symptoms, however, being mild enough not to prevent his enjoyment of the journey. A few days later he crossed by railway from Arequipa to Lake Titicaca in Bolivia, over a pass 14,666 feet above the sea, without any inconvenience. But the morning after reaching La Paz (11,945 feet) he woke up with headache and nausea, which quite prostrated him for twenty-four hours, and then took a final departure. This form of mountain-sickness, so the doctor informed him, generally attacks any new-comer to the town. It is, therefore, quite possible that, if the Jungfrau railway be completed, not a few of the passengers who are hauled up to the summit may not care to "eat, drink, and be merry."

Rising as they do, especially in the more central part, between two regions differing much in meteorological conditions, the Alps afford opportunities, often too ample, for investigating clouds. Their forms may be studied in some admirable illustrations to Ruskin's "Modern Painters,"[1] and in a volume specially devoted

[1] Vol. v. pt. vii. chaps. i.–iii.

to them by Elijah Walton.[1] The delicate and singularly beautiful cirrus, which is apt to be a precursor of weather bad for the climber, seems to float at a great elevation, for, according to the former authority, it clears even the highest peaks; but two or three forms of condensation at a lower level should be briefly noticed. The banner-cloud streams from the lee-side of a peak, contact with which has made visible a vapour-laden current of air till it once more returns to its former temperature. The bonnet-cloud sometimes hovers just clear of a summit, like a flat crescent-cap of white, and its exact history is not easily understood. More often, however, the peaks, even in settled weather, put on their hats for some hours of the day. These clouds often begin to form towards nine o'clock in the morning, increasing for a time in size, till, as evening approaches, they gradually disappear. Thus climbers who wish for an unbroken view endeavour to reach their goal at an early hour. Often, however, mist forms in the valleys before sunrise, not long after which it begins to rise, rolls up the mountain, and is gradually dissipated. The effect of these delicate and filmy, more or less diaphanous veils, alternately hiding and revealing the spires of pines and the broken ridges of rock, is often singularly beautiful, and they may be seen in unsettled weather at other times of the day. But too often the clouds may remain almost at rest, covering everything below a certain elevation. Sometimes their top is comparatively level, above which the higher peaks rise like islands from a sea. I saw this effect very grandly for a time during an ascent

[1] "Clouds, their Forms and Combinations" (1873).

of the Grivola, everything below an altitude of about 10,000 feet being completely veiled. A more local formation of this kind often disappoints the traveller desirous of obtaining a view of the Italian lowland from the crest of the Pennines near the head of the Visp-thal. A cloudless sky is above him as he mounts the snow-fields from the Swiss side. But on reaching the crest he looks down on a sea of cloud, veiling the plain and converting the valleys beneath his feet into fjords. This mist is so thin that, if below it, he would hardly recognise its presence; but from above it is opaque enough to hide the view, with perhaps now and again a partial withdrawal just enough to be tantalising. I had been at least ten times on points which ought to have commanded this prospect before I saw it in full beauty—that, from the summit of the Weissmies, was a thing never to be forgotten. The "Maloja cloud" has a somewhat similar origin. Towards sunset a long tongue of white cloud protrudes from the south far enough to be seen from Pontresina, the result of a change in the set of the vapours, perhaps caused by a more rapid fall of temperature on the northern side, as the evening is approaching.

Occasionally the bonnet-cloud, which has been mentioned above, becomes a turban-cloud, enveloping a single peak. I remember seeing a good instance once from the hut on the Gross Venediger. It commanded a fine view over the limestone mountains to the north-east, most of which were either wholly or very nearly clear; but one isolated summit was completely smothered in a mass of cumulus, which was indulging in its own little thunderstorm. Strangest, perhaps, of all is the aspect of a "cloud cataract." I saw a striking example of this from the Col de Vosa in July, 1875. We had passed the previous night at the Miage chalets, in the Allée Blanche, whence we had perceived, from the frequent flashes of lightning and growls of thunder, that there was a bad storm somewhere to the north of the Mont Blanc range. We crossed the Col de Miage in fair weather, but when we came in sight of the limestone ranges to the north, saw that atmospheric disturbances still lingered in that quarter; clouds festooned or capped their crags, which in one place poured in one great Niagara of vapour over the mural precipice crowning a range.[1]

Thunderstorms are frequent in the Alps, as in most mountain regions, and from the Lake of Geneva, as Byron so graphically describes,[2] we may often watch how

> "From peak to peak, the rattling crags among,
> Leaps the live thunder! Not from one lone cloud,
> But every mountain now hath found a tongue,
> And Jura answers, through her misty shroud,
> Back to the joyous Alps, who call to her aloud!"

The Alpine climber sometimes finds himself actually enveloped by a thunder-cloud. Such an experience, near to the Jungfraujoch, has been described by the late R. S. Watson.[3] A dense cloud had settled upon

[1] On approaching Geneva a few days afterwards I found the vines had been stripped almost bare by hail, the plane-tree leaves torn to shreds at the top and injured in every exposed part below, and the skylights in the town generally shattered.

[2] "Childe Harold," c. iii. 92.

[3] *Alpine Journal*, vol. i. p. 142.

the pass, and snow was falling heavily as his party decended from it. "A loud peal of thunder was heard, and shortly after I observed that a strange singing sound, like that of a kettle, was issuing from my alpenstock. We halted, and finding that all the axes and stocks emitted the same sound, stuck them into the snow. The guide from the hotel now pulled off his cap, shouting that his head burned, and his hair was seen to have a similar appearance to that which it would have presented had he been on an insulated stool under a powerful electrical machine. We all of us experienced the sensation of pricking or burning in some part of the body, more especially in the head and face; my hair also standing on end in an uncomfortable but very amusing manner. The snow gave out a hissing sound, as though a heavy shower of rain were falling; the veil on the wide-awake of one of the party stood upright in the air, and on waving our hands the singing sound issued loudly from the fingers. Whenever a peal of thunder was heard, the phenomenon ceased, to be resumed before its echoes had died away. At times we felt shocks, more or less violent, in those portions of the body which were most affected. By one of these shocks my right arm was paralysed so completely that I could neither use nor raise it for several minutes, nor indeed till it had been severely rubbed by Claret, and I suffered much pain in it at the shoulder-joint for some hours. At half-past twelve the clouds began to pass away, and the phenomenon finally ceased, having lasted twenty-five minutes. We saw no lightning."

Sometimes these storms prove fatal to traveller or guide. My friend, F. F. Tuckett,[1] with his two guides, had a narrow escape on the Roche Melon (11,593 feet). They had been caught on the summit by a thunderstorm, and had taken shelter in the little chapel just below it, and while there "every rock, every loose stone, the uprights of the rude railing outside the chapel, the ruined signal, our axes, my lorgnette and flask, and even my fingers and elbows set up 'a dismal, universal hiss.'" During a lull they had descended hurriedly till they were again obliged to seek protection from a yet more furious storm, in a much larger and more solidly built chapel, called the Cà d'Asti, at a height of 9,396 feet. They had closed the door. Tuckett had seated himself on the step of the altar, the guides were sitting between the window and the door. After five vivid flashes, followed all but instantaneously by sharp, crackling thunder, came another not quite so close, and then, "crash! went everything, it seemed, all at once. . . . We were blinded, deafened, smothered, and struck, all in a breath. The place seemed filled with fire; our ears rang with the report; fragments of what looked like incandescent matter rained down upon us as though a meteorite had burst, and a suffocating sulphurous odour—probably due to the sudden production of ozone in large quantities—almost choked us. For an instant we reeled as though stunned, but each sprang to his feet and instantly made for the door." Once outside, they rushed into the nearest shed. "For the next few minutes the lightning continued to play about us in so awful a manner that we were in no mood to investigate the nature and extent of our injuries," but on

[1] *Alpine Journal*, vol. vii. p. 192.

doing this Tuckett found his hat was knocked in, his pockets filled with stones and plaster, and his right foot painful and bleeding, where it had been struck by one of these missiles. One guide had a hand similarly hurt, and felt acute pain in the thighs; the other, for a time, seemed completely dazed. When the storm drew off they went back to the chapel and found it a scene of ruin. "The lightning had evidently first struck the iron cross outside and smashed in the roof, dashing fragments of stone and plaster upon us, which, brilliantly illuminated, looked to our dazed and confused vision like flakes of fiery matter. It had then encountered the altar, overturning the iron cross and wooden candle-sticks, only three feet from the back of my head, as I sat on the step, tearing the wreath of artificial flowers or worsted rosettes, strung on copper wire, which surrounded the figure of the Virgin, and scattering the fragments in all directions. Next it glanced against the wall, tore down, or otherwise damaged, some of the votive pictures (engravings), and splintered portions of their frames into matchwood. . . . The walls were in two places cracked to within 5 feet of the ground."

Winds more or less local are common in the Alps, coming up and down a valley at different times of the day, but sometimes a strong breeze, almost a gale, may be blowing on the upper ridges of the mountains, while their lower slopes are quite undisturbed. When the north wind brings on a clear, bright day, as it generally does, we often see a little streamer of white spray, like an incipient cloud, drifting away from a snow-peak. The mountain, as they say, is smoking its pipe—but it is not one of peace, for I have more than once known an expedition beaten back, on a perfectly clear day, by the force of the wind and the intense cold.

More dangerous far than this are those sudden storms of wind and snow which set in, often rather suddenly, generally at elevations of 6,000 feet or more, in the later part of the year. Travellers become bewildered, for the air is full of whirling, powdery snow, lose their way, and at last sink down exhausted to die. That fate befel two of our countrymen on the Col du Bon-Homme (7,680 feet), so long ago as 1830, but the memory of it has not been lost. They gradually became incapable of proceeding, and their guides, after having in vain endeavoured to urge them on, were obliged to leave them to their fate.

The Föhn is a wind from the south, hot, stifling, and dry, supposed to come from the deserts of North Africa.[1] The air becomes close and stifling; the sky thickens to a muddy, murky condition; animals become restless, and mankind is conscious of a sense of lassitude and disquiet. It is unfavourable to climbing; and in some villages, while this wind is blowing, fires are extinguished, lest some chance spark, falling on the dry wooden roofs, should start a blaze, which would quickly spread from house to house. The town of Glarus has twice been greatly injured by a fire thus begun; on the second occasion, May 10, 1861,

[1] The correctness of this view, once generally entertained, is now disputed. A discussion of the question will be found in Hann's *Handbuch der Klimatologie* (3rd edition), vol. i. p. 296. Into that, however, it is needless to enter; its effects are the same, whatever its origin.

almost the whole was burnt. But in the spring the Föhn makes atonement for its occasional misdeeds. Before its touch the winter snows disappear with wonderful rapidity. Tschudi says that in the valley of Grindelwald a snow-bed two feet thick disappears in about as many hours, and that the Föhn produces in twenty-four hours a greater effect than the sun does in fifteen days.

The peasants express their estimate of its power in a rather profane saying: "If the Föhn does not blow, the golden sun and the good God can do nothing with the snow."

In fine weather the transparency of the air is often remarkable. Though the Mediterranean can hardly be visible from the summit of Monte Rosa because of intervening mountains, the Viso is clearly seen in one direction, nearly a hundred miles away, and the Adamello in another at more than that distance. Mont Blanc is visible from Notre Dame des Fourvières, close to Lyons, across almost a hundred miles, and I have myself seen it from the railway between Dijon and Macon. At first I mistook the mountain for a cumulus cloud low down on the horizon, but presently the shape became more definite and dark rock ridges perceptible, till shortly before we reached Macon it faded from view in the twilight. The distance could not anywhere have been less than a hundred miles.

On a clear day the blue of the sky, as we ascend a mountain-side, becomes deeper, till occasionally it appears, from one of the higher summits, the colour of a gentian flower. We look, through a far thinner veil of vapour, to where, in Shelley's words, "the sun's unclouded orb rolled through the black concave." [1] There is, I think, a difference in the colour of the sky when regarded from lower positions on the two sides of the Alps. On the Swiss it is a clearer, more ultramarine tint; on the Italian a little nearer to a turquoise blue. The greater abundance of extremely minute particles of water, which produce, nearer to the high peaks, the veil of mist already mentioned, is, no doubt the cause; so that it is analogous with the different hues of the water in the Swiss lakes. In Brienz, for instance, which receives the turbid streams of the Aar and the Lütschine, it is almost green; while the cleaner waters of Thun are blue. Lake Leman shows this change in tint, when it is followed from the delta at Villeneuve to its southern end at Geneva; and when a small stream, accidentally swollen, enters the clear water in one of the large lakes, we can often see a well-defined boundary between the one and the other; the turbid water descending beneath the clear, like the margin of a cumulus cloud which is gradually spreading beneath the surface. The muddy Arve and the clear Rhone, as has often been remarked, flow side by side for a considerable distance without mingling their waters; and this is by no means the only instance. But pure as the latter may seem, as it emerges from its pleasant purgatory in Lake Leman, its tint, which is only surpassed by the marvellous blue in some portions of the Mediterranean, is attributed to residual particles

[1] It was well seen in the ascent of Monte Rosa by T. W. Hinchliff ("Summer Months in the Alps," 1857, p. 111), and I had the same good fortune in 1859, but without the view of Italy.

of almost infinitesimal minuteness, which are still suspended in its waters.[1]

This lake exhibits, as indeed do some others, curious disturbances which long ago attracted attention. These are sudden and rather local oscillations of level, called *seiches*, where the water rises and falls for a height of 2 or 3 feet. It did this on one occasion—in the year 1600—four times through a space of 5 feet. The most probable explanation seems to be inequalities in barometric pressure on different parts of the surface of the lake. Sudden squalls are sometimes dangerous on this and other lakes, for they may capsize sailing-boats and raise waves high enough to swamp small craft. Such a squall, as we used to read, afforded William Tell the opportunity of escape from Gesler's boat and of subsequently giving another proof of his skill as a marksman. But this, according to a sceptical age, is only legend posing as history.

The "mountain glory" of sunrise or sunset, which has now become so familiar to all as not to need description, is an indirect consequence of the presence of aqueous vapour in the atmosphere, and so too is that mysterious "after-glow" which is less often enjoyed. The sun has set; the last crimson hues have disappeared from the highest peaks; their snowfields and glaciers stand out white against the darkening sky as though stricken with the pallor of death, and then, after an interval of several minutes, we see "the snowy summits again tinted, again recovering a kind of life." They once more

[1] The subject is discussed in some detail by Professor J. Tyndall, "Glaciers of the Alps," part ii. sections 6 and 7.

appear in relief, of a "warmer tone—a yellow, more or less inclining to orange—though far more feeble than it was before sunset. Again we see the contrasts between the rocks and the snows disappear; the former assume a warmer and yellower hue, and are again in harmony with the snow." The lower slopes "still retain the cold grey or bluish tint, which previously had spread over everything except the snow; and up to nightfall all the mountains resume and retain the same proportions of colour, of tints, of light and shade, the same general effect that they had before their discoloration and obscurement."[1] This sometimes lingers long, and is due to the reflection of the red rays from the surfaces of particles of water in the neighbourhood and to the west of the zenith, which, though they may be so fine and transparent as to be invisible to the eye, are quite capable of reflecting light.

The stars at night often show the clearness of the mountain air, the number and brightness being far greater than we are accustomed to see in our own country. At one of the Alpine haunts, some 6,000 feet above sea-level, we have only to look up on a clear night to see how the "floor of heaven is thick inlaid with patines of bright gold."[2] But this may sometimes occur even at a lower level. I never saw a more wonderful effect than from Bourg St. Maurice in the Isère valley, though its altitude is only about 2,800 feet. Myriads of stars seemed to become

[1] Translated from a long description of sunset on Mont Blanc by M. Necker (*Annales de Chemie et de Physique*, February and March, 1839. See "Alpine Regions," pp. 152–57).

[2] "Merchant of Venice," Act V. sc. 1.

dimmer and dimmer in the infinitude of distance, and on keeping the eyes steadily fixed on any one spot, specks of light, dim and uncertain in position, apparently materialised out of the darkness. The Milky Way also, brighter than I had ever beheld it in England, was like a luminous curdling spreading in an irregular arch across the heavens.

Such clearness, especially in the distant mountain views by day, is not always indicative of settled fine weather; but the result is so beautiful, that one may be justified in taking no thought for the morrow. Least promising, however, of all is a warm night—that often means the approach of change for the worse. The mountaineer in the Alps often envies the meteorological conditions of the Sierra Nevada, where, during the summer, even a thunderstorm is a rarity, and the weather does not break till the coming of winter, about which there is no hesitation.

The rainfall on the Alps is not large compared with that of some mountain chains. It amounts approximately to 31·5 inches at Geneva, to 33·5 inches at Chur, 39 inches at Sils, 45 inches at Salzburg, in several places of the Tyrol, and at the Great St. Bernard, 47·5 inches at Zurich, and 63 inches at Lugano. In fact, its range does not often fall below 40 inches, or rise above 70 inches. But though some months, as in our own country, are apt to be rather wetter than others, precipitation is spread over the whole year, so that more than a few days of settled fine weather is a rarity. Thus with the pleasant memories of climbs which have been completely successful are mingled too many of those in which the view has been limited to a few yards of impenetrable mist, or the expedition has had to be abandoned; or what is still worse, of days spent in weary waiting at a comfortless mountain inn or a dark and dirty chalet, or even beneath some sheltering rock.

On the higher mountains the light transmitted through the snow produces an effect seldom, if ever, visible on the lowlands. The hole made by an alpenstock or ice-axe shows a delicate tint, varying from a pale green to blue, like that, though less intense, of the light in a crevasse, but sometimes the latter hue is exceptionally vivid. Professor Tyndall records an instance on Monte Rosa. In the morning, during his ascent, he had examined the holes made in the snow by the batons of himself and his guide, Christian Lauener, but the light which issued from them was scarcely perceptibly blue. Snow, however, had begun to fall some time before they reached the summit, and had formed when they left a deep layer, which brought a marked change. "Along the kamm," he says, "I was continually surprised and delighted by the blue gleams which issued from the broken or perforated stratum of new snow; each hole made by the staff was filled with a light as pure, and nearly as deep, as that of the unclouded firmament. When we reached the bottom of the kamm, Lauener came to the front, and tramped before me. As his feet rose out of the snow, and shook the latter off in fragments, sudden and wonderful gleams of the blue light flashed from them."[1] Sometimes also the snow has shown actual phosphorescence. Mr. Thurstan Holland records an

[1] "Glaciers of the Alps," p. 132.

instance, also in new-fallen snow, on the descent from the Rauriser Tauern to Heiligen-blut: "As we were crossing one of the patches of snow, I observed that the snowy particles, which fell from my shoes, appeared like a number of bright phosphorescent sparks."[1] He saw it also when a companion walked in front, and compared the effect, except that the sparks were of a pale phosphorescent colour, to that seen at night when a horse strikes his shoe against a stone. The hour was late, for there was not light enough to read their watches, and the sky was overclouded. Mr. Holland refers to instances observed by other travellers, and the explanations which had been offered, but those we must abstain from discussing.

[1] *Alpine Journal*, i. p. 143.

CHAPTER XI

THE VEGETATION OF THE ALPS

A DESCRIPTION of the Alpine flora in any detail would be, to all but botanists, unless accompanied by coloured plates, little better than a catalogue of unknown names. We must, therefore, not attempt more than to give a general account of the succession of plants met with in ascending a mountain, and illustrate this by choosing as examples those of which the genus at least is likely to be well known to all who take an interest in the gardens and open country in our own land. A further difficulty is the impossibility of making more than general statements in speaking of the range of plants in the Alps. The chain forms a great barrier wall between Central and Southern Europe. Thus, just as an isthmus divides two seas, the faunas of which may be very different, so the Alps part two floras, which to a considerable extent have spread from separate sources and had a different history. The climate also is by no means the same at corresponding altitudes in every district, as is only to be expected in a chain which extends over about 10° of longitude and nearly 4° of latitude, with a breadth of from 100 to 120 miles. The vegetation of the transverse valleys south of the Pennine range enjoys, as can be seen at a glance, a more genial climate than that of corresponding valleys on the north, and the same is true, to take a special example, of corresponding parts in the Val d'Aoste and the valley of the Rhone. We realise the change in passing from north to south through one of the great tunnels beneath the Alpine watershed, and most of all in that under the Simplon Pass. At Brieg pinewoods dominate in the view, and there is a certain sternness in the landscape. We emerge, though it is a rocky glen, among luxuriant brushwood, deciduous trees holding their own with the pines, and by the time we have reached the same level as that of Sierre on the northern side find Spanish chestnuts and mulberries, figs and maize to be flourishing around us. Thus the range of any group of mountain plants is distinctly higher on the southern than on the northern side of the chain—the difference in extreme cases (not including the Maritime Alps) being not much less than 1,000 feet. The nature of the rock, the aspect of the place, the proximity or absence of large snowfields, all produce an effect, so that numerical statements in the following remarks can only be approximate, and will be more accurate in some parts of the chain than in others.

The height of the lowland from which the Alps definitely begin to rise is from about 1,300 to 2,000 feet along their northern face, perhaps rather lower on their western, and generally less than 1,000 feet on their southern one. Thus the flora on the margin of the mountains corresponds with that of the adjacent lowland; that is to say, of the neighbouring parts of Central Europe. As we rise above sea-level, the plants characteristic of an upland region make their appearance, and we pass from zone to zone till a height is reached where vegetation is stunted and plants begin to be found which, in arctic regions, are growing at the sea-level. On the northern side of the Alps the lowland zone gradually ends at an altitude of about 2,500 feet. In it the vine does well, orchards flourish, and the larger fruit trees generally are abundant; maize can ripen and the ordinary cereals bring good returns. Outside the mountains vines clothe the hillsides; within them, however, they soon disappear from the slopes of valleys on all but the most favourable aspects. In the Valais, for instance, the grape ripens well up to quite 2,000 feet. Maize may be found at a rather greater elevation, and wheat sometimes grows at levels above 4,000 feet, but only in very favourable positions, for it seldom ripens a good crop beyond 3,000 feet. "The general line of cultivation in the Alps may be placed between 2,700 and 3,000 feet, though there are naturally many exceptions to this."[1] As we rise in the mountain regions towards 4,000 feet, the more delicate fruit-bearing trees speedily follow the vine and maize; and though the walnut flourishes as a foliage tree almost up to this limit, it has ceased to ripen its fruit. Deciduous trees gradually give place to conifers, and among the former the birch predominates. A change is also to be noticed in the flowering plants; the more delicate representatives of the lowlands disappearing and the precursors of the hardier mountain vegetation beginning to assert themselves. But, as we have already said, the change is more slowly perceptible on the southern side of the chain.

[1] Morell, "Scientific Guide to Switzerland," p. 194.

Here the vine is cultivated up to about 3,300 feet;[1] the Spanish chestnut ranges nearly as high, and is a handsome tree in the lower parts of the Pennine valleys at elevations not greatly below 3,000 feet. Among the shrubs the barberry (*Berberis vulgaris*) and the sallow-thorn (*Hippophae rhamnoides*), with its silvery leaves and bright orange berries, are abundant on the stony tracts in the neighbourhood of torrents; the Dane's-blood elder (*Sambucus ebulus*) is common; wild currants and gooseberries are not rare. The alpine strawberry, raspberry, and a second species (*Rubus saxatilis*) which is of lower growth and has a small pleasantly acid fruit, make their appearance, together with the bilberry (*Vaccinium myrtillus*), and the cowberry (*V. vitis-idæa*), which range up to at least 6,000 feet. Among the flowering plants, gentians become conspicuous on the grassy mountain sides; such as the handsome yellow one (*Gentiana lutea*) and the purple (*G. purpurea*), and most beautiful of all, the *G. asclepiadea*, which I have but rarely seen, though it grows well on the Rock Garden at Kew. At this and lower levels the pale-lilac field gentian, *G. campestris*, abounds, as in some parts of our own country. With the first and second we often find *Veratrum album*, handsome and rather similar in growth, but less effective in flower. The purple monkshood (*Aconitum napellus*) becomes common; I remember to have seen it in abundance for the first time near the Devil's Bridge, which unhappily tumbled down into the Reuss over twenty years

[1] On the northern side the vine is grown, as in Germany, almost like a raspberry-bush. On the southern it is often trained over a framework supported by posts, much as in a greenhouse.

ago.[1] The far more beautiful large blue larkspur (*Delphinium alpinum*) may also be found, but it is a rarity. Saxifrages, often such graceful flowers, become common; the finest of them (which also ranges rather higher) being *S. cotyledon*; and its spiral group of delicate white flowers often exceeds a foot in height. It is a very cautious plant, usually growing on cliffs or in ravines that are quite inaccessible, as if it knew that its beauty would attract the spoiler. Yet the finest I ever saw, nearly 2 feet in height, was growing close to the road going up the Gadmenthal to the Stein Glacier. More than one species of stonecrop (*Sedum*) and of houseleek (*Sempervivum*), two of thyme (*Thymus*), with bedstraws (*Galium*), and clovers (*Trifolium*) are common, and we may find the dark columbine (*Aquilegia atrata*), the Grass of Parnassus, and the attractive cream-coloured foxglove (*Digitalis lutea*). The pretty little cyclamen (*Cyclamen Europæum*) is abundant in the Salzkammergut and occasional (so far as I know) in Switzerland. Much more rare is the lady's-slipper (*Cypripedium calceola*), one of the most beautiful of Alpine plants. Harebells (*Campanula*) of two or three kinds are abundant; some of the larger species, together with campions (*Lychnis*), the pink *Persicaria*, and other plants, more or less familiar in aspect, converting the valley-meadows, for another 1,000 feet, into veritable flower-beds, which perhaps delight the traveller more than they improve the hay. Of these harebells, a pretty one, rather less than a foot in height, *C. barbata*, appears within this zone, but like not a few other flowers is more characteristic of the next one.

[1] In 1888.

This, which may be regarded as bringing us well into the true Alpine flora, extends from 4,000 to 6,000 feet. Here two species of pink rhododendron (*Rhododendron ferrugineum* and the less common *R. hirsutum*) cover the mountain side with an even richer tint than the heath and heather of our own land. These, by the way, are not generally abundant in the Alps. Another and much smaller species, which at first sight would hardly be supposed to belong to the same genus, *R. chamæcistus*, is common in parts of the Eastern Alps. The golden-ball, *Trollius Europæus*, to be found in our Welsh valleys, is plentiful. The martagon lily (*Lilium martagon*) is often seen, and more rarely the orange lily (*L. bulbiferum*), of which I saw more than ever before in July, 1911, on the way from Airolo to the Val Piora. The genus *Sedum* continues to be represented on walls and rocks. So does the *Primula*, but the most richly coloured species ends its flowering before July, and only the delicate pink-coloured one (*P. farinosa*) is still abundant on damp ground. The delicate St. Bruno's lily (*Anthericum liliago*) becomes commoner as we approach the upper limit of this zone, but I have only once seen it in great abundance, and that was on some pastures at the base of the Marmolata, on the way from the Sottaguda gorge to the chalets of the Fedaia Alp. The narcissus (*N. poeticus*) with two other species seems to range far. According to Ruskin the hill meadows above Vevey in spring-time rival in whiteness the snows of the Dent du Midi, but as I have never been able to visit the Alps at that season I have but once seen it in its glory. This was on the Col du Lautaret (6,808 feet), where it grew as thickly on the upper pastures as the daffodil in some meadows or dells in England, where the plunderer of flowers can be kept at bay.[1] Very pretty, but rather rare, is the pale purple Alpine clematis (*C. alpina*), and the more beautiful blue columbine (*Aquilegia alpina*), which occurs in small and rather widely separated colonies.

For a thousand feet or more above the 6,000 feet limit we find ourselves on a zone where the flowers are distinctly Alpine, and have not begun to diminish very notably in the number of species. Pinks of three or four species, in colour varying from a dull crimson to a pale mauve, have continued from the lower limit of mountain plants. The genus *Ranunculus* is well represented by more than one conspicuous white-flowered species, and the primrose-coloured anemone (*A. sulfurea*) is at home over the above-mentioned zone. I have met with them in many places, but never so abundant as on the slopes of the Heuthal near Pontresina, and on those descending from the Furka Pass direct to Gletsch. In July, before the cattle come up, the Alpine pastures over this zone are in perfection. The denser pine-woods have been passed; the trees are not seldom stunted, and frequently quite scattered. The Alpine flowers have no other competitors than themselves in the struggle for existence. Few of them are large—it is not often that we find one rising more than about 6 inches above the ground, though the yellow arnica (*A. montana*) overtops its neighbours—but most of

[1] As this was in 1887, and I did not preserve a specimen, I cannot say more than that it was not *N. poeticus*, the only species then known to me.

them are bright-coloured. In summer I know no place richer in flowers at this season than the slopes around the Lago Ritom. The air is scented by the blossoms of that lowly shrub *Daphne striata,* for which in many places we may seek in vain. The turf is spangled with the purple and gold Alpine aster (*A. alpinus*), and the smaller but rather similar *Erigeron alpinus,* which extends lower down, with a species of ox-eyed daisy (*Chrysanthemum alpinum*), which has a wide range. So also has the avens (*Dryas octopetala*), with its flower of delicate white, which seems to flourish best on slightly uneven ground. There is the yellow mountain geum (*G. montanum*), with sundry smaller flowers of that tint, such as *Potentilla* and *Senecio.* That also is the colour of the little *Viola biflora;* but far more conspicuous is the larger purple pansy (*Viola calcarata*), sometimes so abundant as to give a tint to the herbage. There are gentians —the deep blue bells of *G. acaulis,* the clustered flowers of the low-growing *G. verna,* often so close together as to form patches, a hand's-breadth wide, of the richest ultramarine, besides one or two smaller species, among which the little snow gentian (*G. nivalis*) begins to be seen. Along with it appears the rich pink of the little mountain campion (*Lychnis alpina*), and the delicate soldanella (*S. alpina*), which may be seen springing up on the track of the melting snow, through which its pale lilac flower contrives sometimes to force a passage. Hardly less prompt in greeting the unveiling of the sun is an anemone (*A. Halleri*), with flowers of slightly darker tint and woolly exterior, which is followed by other species, including more than one of ranunculus. Of the orchis group, which is well represented on the lower slopes, the little nigritelle (*N. angustifolia*) soon attracts notice with its deep red-purple flower and odour of vanilla. There is also the forget-me-not (*Myosotis alpina*), the turquoise-blue of its flower even richer than that of the lowland species. Of the pink flowers the soapwort (*S. ocymoides*) has come up from a lower level, and at least one species of *Dianthus* still flourishes, yet more richly tinted than it was below. There will be found, as have been for some distance, more than one species of the offensively named louse-wort (*Pedicularis*); but most effective of all is the moss-campion (*Silene acaulis*), the low-growing flowers of which are so closely set as sometimes to form an unbroken patch of delicate pink nine or ten inches in diameter. In stony places we have seen for some time the pink blossom of the dwarf willow-herb (*Epilobium Fleischeri*), and the little creeping Alpine toadflax (*Linaria alpina*), with its purple and yellow flower, together with the Alpine cress, small in size and in flower, all which are among the first to find a home on the dry débris of moraines. At this elevation the edelweiss (*Gnaphalium leontopodium*) is at home, but it may also be gathered below it, like the commoner European species (*G. dioicum*), which seems capable of accommodating itself to a vertical range of quite 7,000 feet. The edelweiss is a plant which, though found in almost every part of the Alps, is distinctly local in occurrence, and its range, as a rule, is from about 5,000 to 7,000 feet. The popular idea that it prefers to grow where life must be risked in gathering it is an illusion. It may, no doubt, be found in such places, and there of course it will linger the longest; but I have seldom, if ever, come across it in any difficult part of a mountain ascent. It grows, or did grow—for probably the tourist has exterminated it—on the stony slope leading to the Triftbach Fall, above Zermatt; in a similar place, almost as easy of access from Saas Grund, on the right bank of the valley, and in like positions, in each of the other Pennine valleys to the west. I found it plentifully, some quarter of a century ago, on the grassy alp within a short walk of the Tosa Falls Inn (5,490 feet), but I have never seen it so abundant as on a ridge of the Pizzo Ucello, above San Bernardino. This was a mixture of rough grass and small projecting edges of rock, along which any one could walk, and on this broken ground, which I believe to be its favourite habitat, edelweiss was growing almost as commonly as daisies in a meadow. It is a quaint rather than a pretty flower, but as it has become the centre of a group of legends, it finds a ready sale among ordinary tourists, and is hunted down by those who make a living out of them. Thus, like others of the more interesting members of the Alpine flora, it is becoming scarcer; but the protection of the law may save it from extinction.

A change gradually appears in the character of the flowering plants as we approach and pass the level of 7,000 feet. They are only represented by dwarfed forms, of which the most noteworthy is the lowly *Azalea procumbens*, with its tiny pink flowers, which has been already found for some distance. The moss-campion continues, but seems to become more conscious of a struggle for existence, and its place is taken by a species of *Androsace* (*A. helvetica*), similar in habit, but paler in colour, though hardly less beautiful. Of the gentians, the little *G. nivalis* still continues, as well as some sturdy louse-worts, and a new species of ranunculus (*R. glacialis*) becomes common. Rather procumbent in its habit of growth, with cup-shaped flowers, white within and pinkish outside, it seems able to flourish on any stony ground, provided that be rather moist. The little purple saxifrage (*S. oppositifolia*) is quite at home, and some of the smaller harebells are occasionally seen, but seldom in any quantity, perhaps the most noteworthy being *C. cenisia* and the more restricted *C. excisa*, both found in the upper part of the main valley above Saas. The little *Eritrichium nanum*, with its lovely azure-blue flower, so delicately scented, now becomes locally common, and ranges high. I have found it very plentiful in positions on either side of 9,000 feet; for instance, on the upper part of the descent from the Piz Languard into the Heuthal, near the Hotel Weisshorn and below the summit of the Mittaghorn, above Saas, on the rocks under the Gorner Grat and on the Italian side of the Col de Séa, in the last three cases at about 10,000 feet. But flowering plants become sparse and rare, at any rate on the northern side of the watershed, when we approach the former limit, though now and again they maintain themselves at great elevations. I found *Androsace glacialis*, a louse-wort, and another plant in flower on the Col de Séa at 10,115 feet; the same *Androsace* with *Saxifraga bryoides* on the summit of Mont Emilius (11,677 feet), *Campanula cenisia* on the Grivola, just over 12,000 feet, and at about the same elevation Mr. J. B. Masterman came upon *Saxifraga oppositifolia*.

A tuft of an *Androsace* which I saw on the Matterhorn was perhaps rather above this level.[1]

The Alpine trees claim a little more notice than they have as yet received. Those with deciduous leaves are gradually replaced by conifers, though the larch, which satisfies both conditions, is abundant on the mountain slopes, and it extends up them, in round numbers, from 4,000 to 7,000 feet. It does well up to about 6,000 feet, and specimens may occasionally be seen over 100 feet high and 4 or 5 feet in diameter 3 or 4 feet from the ground. Growing both with the larch and alone, the common spruce (*Pinus abies*) abounds in the Alps. "Perhaps it is nowhere more beautiful than in the limestone zone, which extends along the northern face of the Alps from Savoy to the Tyrol, where the vast sweeps of purple forests, broken here and there with exquisitely green alps, and surmounted by grand crags, offer some of the most beautiful combinations of wild and pastoral scenery that can be conceived."[2] Ruskin's word-picture of these groves is so accurate that it ought to be quoted.[3] "Other trees show their trunks and twisting boughs, but the pine, growing in either luxuriant mass or in happy isolation, allows no branch to be seen. Summit behind summit rises in pyramidal ranges, or down to the very grass sweep the circlets of its boughs;

[1] On Mont Emilius and the Grivola the plants were named by my companion, the late W. Mathews, an excellent botanist. *Ranunculus glacialis* was found on the Schreckhorn at 11,000 feet, and *Cherleria sedoides* on Monte Rosa at 11,770 feet (Morell, *ut supra*, p. 211).

[2] "Alpine Regions," p. 211.

[3] "Modern Painters," vol. v. p. 84.

From a sketch by] [*Mr. E. T. Compton.*

27. ST. CYPRIAN AND THE ROSENGARTEN GROUP.

To face p. 266.

so that there is nothing but green cone and green carpet. Nor is it only softer, but in one sense more cheerful, than other foliage; for it casts only a pyramidal shadow. Lowland forest arches overhead, and chequers the ground with darkness; but the pine, growing in scattered groups, leaves the glades between emerald bright. Its gloom is all its own; narrowing into the sky, it lets the sunshine strike down to the dew. And if ever a superstitious feeling comes over me among the pine-glades, it is never tainted with the old German forest fear; but is only a more solemn tone of the fairy enchantment that haunts our English meadows."

In the Dolomite region of the Tyrol and in Carinthia the pine has a more tapering growth, which has been attributed to the practice of cropping the side branches to obtain winter fodder for the cattle. But, after frequently examining these trees during my earlier journeys, I think the form is a natural one, though how far it is an improvement on the scenery is open to question. Occasionally their branches droop to a much greater extent than in the ordinary kind, for they "bend round rather sharply a few inches from the bole, and slope down almost parallel with it, curving slightly upwards near the extremity. I passed through a wood of such trees on the eastern side of the Tre Croci Pass (Val Auronzo), some of which were veritable giants; lower down they assumed their usual growth. I also noticed that the larches in this neighbourhood appeared to have their side branches comparatively small."[1] Less common is the silver fir (*P. picea*),

[1] "Alpine Regions," p. 212.

which is more abundant in the lowlands and on the Jura; in fact, it seldom extends above 5,000 feet, though in the Pennines it has been found about 1,000 feet higher. In general appearance it resembles the spruce, but can be easily distinguished by the silvery tint of its bark and on the under side of its leaf. Not less beautiful than either of these, though more sporadic in habit, is the arolla, or arve (*P. cembra*), with its dark green and densely clustered foliage. "A well-grown arolla is from 50 to 80 feet high, the circumference of the trunk a little above the ground being a dozen feet or so. The cone contains some twenty or thirty little nuts with a white kernel, which has a pleasant taste, resembling that of an almond, but slightly resinous." It is evidently attractive to the nutcracker.[1]

The Scotch fir (*Pinus silvestris*) is also sporadic in distribution, but locally abundant, and has about the same range as the silver fir. A forest of it extends for a considerable distance along the valley of the Rhone in the neighbourhood of Sierre, and ascends the steep slope towards the entrance of the Val d'Anniviers. In this mistletoe, which in the lowlands is freely parasitic on the usual trees, grows abundantly. A pine of curious habit, called *knieholz* or *latschen* in German, and *P. pumilio* by botanists, appears in the Engadine, and becomes abundant eastwards, especially in the Dolomite region. It trails along the ground often for some yards (downhill if on a slope); "then it rises in a bold, sweeping curve, throwing out branches which

[1] "Alpine Regions," p. 213.

all point sharply upwards, till their extremities are nearly vertical . . . the long snake-like trailing trunk, of a reddish-brown colour, does not throw off any important branches . . . the upper part forms a bushy shrub, from 5 to 15 feet high; hence, so a dwarf-pine scrub generally a little overtops a man's head."[1] Thus it is often a nuisance to the rambler, for the bottle-brush tops become a natural *chevaux-de-frise* when he is ascending, and the slippery trailing stems are apt to bring him, during a descent, into a sitting position more promptly than is pleasant.

Two junipers are common in most districts. The dwarf variety (*Juniperus nana*) of the well-known shrub, from the berries of which schiedam is made, grows on stony tracts, forcing its way almost to the limit of the snow, for I have seen it in fair quantity on the flank of the Pelvoux at about 7,300 feet, and yet 1,000 feet higher by the side of the Glacier Blanc in Dauphiné. It was welcome in both places, as it provided fuel for a bivouac fire, with, however, the drawback that its smoke is remarkably pungent. The other species (*J. sabina*) is more local in its habits, but by no means rare. It appears to occupy a lower zone, and is a more graceful shrub, "covering the slope with its long curving boughs; not hard and rough, as with purpose obstinate though often baffled, but lissom and undulating. . . . The leafage, too, is not bristly, coarse, grey, and dull in colour, but full, rich, and green, more like that of a procumbent cypress."[2]

Ferns are common in most parts of the Alps (least so, perhaps, in the northern valleys of the Pennines),

[1] *Id.*, p. 214. [2] *Id.*, p. 216.

and the majority are identical with those of Great Britain, but some of those which are very rare with us are common in the Alps. A few species make their way nearly up to the snow-line, but others are limited to the lowest slopes. The least adventurous is the delicately graceful maiden-hair *Adiantum Capillus-Veneris*, which I have seen only in two or three of the Italian valleys. It grows near Orta and Varallo, being plentiful on the descent to the latter place from the Col de Colma (3,091 feet), so that it must be able to stray up from the Mediterranean to not very much below this elevation. The king fern (*Osmunda regalis*), stately as its name implies, also keeps to the lower valleys. Of the genus *Lastræa*, to which some of our commonest and handsomest English ferns belong, most of them do not range very high, *L. rigida* and the sweet-scented *L. oreopteris* going above the others. The lady fern (*Athyrium filix-femina*) with *Polystichum aculeatum* and *angulare* also frequent the lower regions; but the holly fern (*P. lonchitis*) is abundant over all parts from 5,000 to 8,000 feet, though it seems to flourish better in the limestone than in the crystalline districts. In the former, wherever the rock has been worn into channels, it nestles in them, sending up fronds, which are often quite half a yard in length. The parsley fern (*Allosorus crispus*) is also a mountain-lover, and ascends almost as high as the last one, but perhaps is more at home on the crystalline rocks.

The common brake (*Pteris aquilina*) is confined to the lower slopes; so is the hart's-tongue (*Scolopendrium vulgare*), and the little *Grammitis ceterach* with its scaly leaves. The genus *Polypodium* is represented by its English species, with an additional one *P. rhœticum* in the district from which its distinctive name is taken, and they range up to near the limit of trees. The beech-fern (*P. phegopteris*) and the oak-fern (*P. dryopteris*) are abundant and so is the limestone-fern (*P. calcareum*), on the rocks from which it is named. Another and larger species *P. alpestre*, which does not descend so low as the others, is commoner than is generally supposed, but so much resembles the lady fern as to be easily overlooked. The spleen-worts (*Asplenium*) are well represented, besides having in the Eastern Alps two species which are not British. *A. lanceolatum* and *A. fontanum*, both of which are rare with us, are local in Switzerland; the latter, which some think ought not to be included in British lists, is fairly abundant in certain limited areas; as, for instance, in the Combe de Malaval (Dauphiné), between St. Laurent du Pont and the Grande Chartreuse, at Les Etroits du Ciel (above Moutiers) in the Isère valley and on the way to Sepey in the Val des Ormonds. The black maiden-hair (*A. adiantum-nigrum*) is also rather local. The common maiden-hair (*A. trichomanes*) and the wall-rue (*A. ruta-muraria*) are abundant in the less elevated regions, above which the former gives place to the mountain-loving green spleen-wort (*A. viride*), which has the same habit in Britain. *A. septentrionale*, which is a rarity with us, is extremely abundant in the Alps, but always on the crystalline rocks. One may ramble for miles over the limestone districts without seeing a single specimen, but no sooner do the gneisses and schists rise to the surface than this little grass-like fern makes its appearance in every favourable crack. Similarly restricted, but much rarer, is its equally small, and with us still scarcer, relative (*A. germanicum*). I have found it near the chalets of Ailefroide in the Val Louise, near Salvent in the Val de Trient, on the Col de Colma, near Chiavenna, and in two or three other localities. The northern-hard-fern *Blechnum boreale* is common in parts of the Alps and approaches the tree limit. The brittle bladder-fern (*Cystopteris fragilis*) may be found well over 5,000 feet, and *C. alpina* is much less rare than it is among our hills; I have gathered it between the Dauben See and the Gemmi Pass; that is, some 7,400 feet above the sea-level. *Cystopteris montana*, like *Polypodium calcareum*, to which it has a considerable resemblance, is a lover of the limestone, and is fairly common in certain places; as, for example, about the Diablerets, near Rosenlaui, in the neighbourhood of Engelberg, and near Landro and Cortina in the Dolomites. It generally keeps rather below the 5,000 feet limit, but I have found it well above this in the first and last of these districts. I have seldom seen either species—*ilvensis* or *hyperborea*—of the genus *Woodsia*, such rarities in our own mountains, but I have once or twice found them, usually in the Tyrol. On the other hand the moonwort (*Botrychium lunaria*), rare and local in England, is extraordinarily abundant on the upper pastures, at least as high as 7,000 feet—its fronds often giving a tawny tint to the grass.[1] The adder's tongue (*Ophioglossum vulgatum*) I have never seen,

[1] There is a second species in the Rhætian Alps.

perhaps because it is early in its appearance and departure.

Our British species of club-moss (*Lycopodium*) are also found in the Alps. The stag's-horn (*L. clavatum*) is common, but does not mount so high as the more sturdy species (*alpinum* and *selago*), which are very abundant, the latter growing almost to the verge of the snows. *L. annotinum* is more common than with us, and a stranger, the delicate *L. helveticum*, is sometimes rather abundant, creeping among damp mosses in the shade of the trees; as, for instance, in the neighbourhood of Engelberg.

We must leave almost unnoticed mosses, properly so called, and lichens, beautiful as they are, except one form of the latter, the long "chamois-beard" lichen which drapes the aged firs with a vesture of pendulous threads. When every other form of vegetation disappears the lichen still persists, brightening the rocky peak with spots of grey and yellow and red. I think I remember it on the summit of Monte Rosa, I know that it exists on the Grivola (13,030 feet). Those who have seen it in these lonely fastnesses can appreciate Ruskin's enthusiastic praise of these plants, "the humblest of the earth-children."[1] "Strong in lowliness, they neither blanch in heat nor pine in frost. To them, slow-fingered, constant-hearted, is entrusted the weaving of the dark, eternal, tapestries of the hills; to them, slow-pencilled, iris-dyed, the tender framing of their endless imagery. Sharing the stillness of the unimpassioned rock, they share also its endurance, and while the winds of departing spring scatter the white hawthorn blossom like drifted

[1] "Modern Painters," vol. v. p. 102.

snow, and summer dims on the parched meadow the drooping of its cowslip-gold,—far above, among the mountains, the silver lichen-spots rest, star-like, on the stone; and the gathering orange-stain upon the edge of yonder western peak reflects the sunsets of a thousand years."

One other humble and even less conspicuous member of the vegetable kingdom must not be forgotten. This is the tiny alga, *Hæmatococcus nivalis*.[1] which produces the red snow often mentioned in the accounts of Arctic voyages. I have not seldom come upon it in positions from rather above the snow-line to about 10,000 feet, but "my first acquaintance with it was on a snowfield near the Viso, and so far as I know, it is rather more frequently found here, and in the neighbouring district of Dauphiné, than in any other Alpine region. There was a reddish-brown tint upon the snow, which at first I took for dust blown from some rocks which were at no great distance: but when we walked over it our footmarks were distinctly of a dark crimson-red colour, as if we had first stepped upon some wet gravel—such as is common in the red sandstone districts of our Midland counties. On taking up a little of this staining matter, I at once saw that it was not dust from any rock, and a closer examination showed its real character. Under the microscope it appears as a minute crimson boss, something like a full-blown rose." [2]

Mr. F. F. Tuckett, one of the earliest and most

[1] Its name and nature have been disputed. It was at one time called *Protococcus*. Dallinger ("The Microscope," &c., p. 558) inclines to regard it as a *Palmella*.

[2] "Alpine Regions," p. 149.

successful explorers of Dauphiné, mentions the occurrence of a yellow snow. This, however, is no doubt produced by the pollen from one or more species of fir, for it was proved to be the colouring material of a "yellow rain" which fell a few years ago in England.

CHAPTER XII

WILD ANIMALS OF THE ALPS

WILD mammals, especially those of larger size, are becoming rarer in the Alps. The Brown Bear (*Ursus arctos*) is now probably restricted to the forest-clad slopes near to Zernetz in the Engadine. There, formerly, they could sometimes be seen even from the high-road, as happened in the year 1860, when they were unusually numerous. Berlepsch [1] tells several stories of encounters with them in the few years prior to that date, and says that they were also not rare in Canton Valais, and sometimes met with in the Graians, but from both these I believe they have now disappeared. One was killed, after a dangerous encounter, near Dissentis in 1838, and towards the end of the eighteenth century they sometimes took toll of the flocks and herds in the Oberland, but the last slain within the limits of Canton Bern was in 1819.[2] I once saw the traces of a bear on the snow—that was in 1867—near the top of the Passo de Val Viola,[3] about 7,900 feet in height, when I had come up the

[1] "The Alps" (translated by L. Stephen), p. 385.

[2] W. A. B. Coolidge, "The Alps in Nature and in History," p. 47.

[3] J. Ball ("Alpine Guide: Central Alps," 1866) mentions having seen the carcase of a partly devoured cow in much the same position —probably about the year 1850.

Val di Campo on my way from Pontresina to Bormio. About half a dozen, however, are maintained as guests of the city in the great circular bear-pit on the right bank of the Aar at Bern, where their comical attitudes and ways make them an unfailing attraction to visitors. Their appetite for cakes and other good things, especially carrots in their season, is apparently insatiable. Canton Bern has the bear for its arms, so the creature figures everywhere in its capital: on fountains and clocks, on buildings and monuments, disputing precedence with the chamois in the shops where wood-carvings are sold.

Wolves have also become rare, but they occasionally occur in all parts of the Alps.[1] They are, however, fairly common in the Jura, where, for obvious reasons, they became rather numerous and formidable after the Franco-German war, forty years ago. But I believe they are never seen by the summer traveller. The lynx is seldom, if ever, found except in the above-named forests of the Engadine.[2] The fox is more common, but is rarely met with. I have only once seen it, in the year 1900, and that was a fine specimen. It was sauntering along the bed of the glen leading from Arolla to the Pas de Chèvres. As I happened to be on a path some couple of hundred feet up the slope, and about as many yards away, the animal did not see me, so I watched it at my leisure till it passed behind a rock. It appeared to me

[1] Tschudi, "Les Alpes" (transl. 1859), speaks of their occasional occurrence in most parts of the chain.

[2] Tschudi (*ut supra*, p. 487), speaks of them as occurring at that date, though very rarely, in most parts of the Alps, and not common even in the Engadine.

slightly stouter in build, and greyer in colour than its English representative. Amusing stories are told of its craft by Tschudi and other writers, especially of the way in which, as it objects to the labour of digging a burrow, it waits till the badger has performed that task, and then by a simple process, and without resorting to teeth and claws, serves what may be called a writ of ejectment. The latter animal is not rare, but, as in England, owing to its nocturnal habits, is but seldom seen. It ranges up to a considerable height above sea-level, especially in the Eastern Alps. The wild cat may still linger. Its latest haunts on record were in the Glarus Alps and the forests of Canton Bâle, which, however, are, strictly speaking, outside our limits; but it has now practically become extinct. The stone-marten (*Martes foina*) still lives in the pine forests, but is rarely visible. I have once or twice seen it, but have unfortunately forgotten the localities. Not so the little squirrel, which can often be watched scuttling up and down the pine-trees or running on the ground from one to another. The otter frequents the banks of the rivers and lakes, but belongs to the lowlands rather than the mountains. The beaver, also, with the same haunts, existed till the earlier part of the last century, for it is mentioned in a list published in 1817 as occurring at several places in the Oberland, though rarely; but I believe it has now disappeared from the Alps, though it lingers, or did so till very lately, on the Rhone outside their limit. The rabbit is hardly Alpine; the brown hare (*Lepus europæus*) keeps to the lower districts, not ranging higher than from 4,000 to 5,000 feet above sea-level, in which zone I once saw one near Bormio; but the blue hare (*Lepus variabilis*) wanders up to 9,000 feet. I have not, however, often seen it. The marmot (*Arctomys marmotta*) frequents the bare mountain sides between the summer snow-line and the upper limit of the tree region, where its shrill whistle is often heard; but a quick eye is required to see the little creature, which generally differs but slightly in colour from the rocks. They sometimes form little groups, but at the first alarm they scuttle away to their burrows, which are much like rabbit-holes, usually having the entrance under a slab-like boulder. Still, now and again the sentinel may be seen, sitting upright on his haunches, and perhaps others of the party, if one happens to be approaching quietly. I have myself come across a fair number, and in my earlier wanderings occasionally eaten them. The flesh is something like that of rabbit. About the middle of October they retire into winter quarters, a dozen or so in a burrow, which is plugged up a few feet below the entrance with earth and hay. There they double themselves up and pack close together for their six months' sleep, during which they neither eat nor drink. Life itself goes on at the slowest possible pace, for the animal during this time is said to respire about as many times as it would do in a couple of days of its ordinary existence. The young—three or four in number—are born in June. They are easily tamed, and a captive marmot is, or perhaps more often was, amongst the devices for extracting centimes from the tourist's pocket in the more frequented parts of the Alps, and might be seen with a Savoyard boy even in the streets of London. A pair, kept in a cage at Saas Grund, in the garden of the Hotel Monte Moro, took crusts and green food, for both of which they seemed to have a boundless appetite, from the fingers of any visitor.

The wild boar does not, so far as I can discover, extend its ranges into the Alps ; and the stag (*Cervus elaphus*) restricts itself to the forests on the lower slopes. Here, in the North-eastern Alps, it is common, but only by means of careful preservation. In the French and Swiss Alps it is practically unknown. In the first-named region the roedeer is fairly abundant, ranging up to about 5,000 feet, but is, I think, now absent from the others. I have only once come across it alive, and that was in descending from the Steinerne Meer to the Königssee. It must, however, be common in that region of the Tyrolese and Bavarian Alps, for I remember that "rehbraten" was almost always an item on the *menu* of hotels in the Salzkammergut.

But no wild animal is so thoroughly identified with the Alpine region as the chamois (*Antilope rupricapra*). Its ordinary range is from about 6,000 to 10,000 feet, and it has been met with, especially in Styria, as low as 3,500 feet. In winter also it is often driven down to the level of the pine-woods. Formerly it was comparatively common in all parts of the Alps, but the increase of tourists has produced the usual results, and at one time there seemed to be some danger of its disappearing from Switzerland. That, however, has been averted by the wise action of the Swiss Government, which, in addition to maintaining the usual laws for the protection of game, closes whole districts for several years, so that the animals can increase and multiply in peace, and thus wander away to replenish the mountains outside those limits. According to an interesting paper recently published,[1] they are on the increase everywhere, except in the Italian Alps, where it seems only possible to defend them from human enemies in the royal preserves on the mountains near Cogne. In the Alps of Bavaria and the Northern Tyrol they have

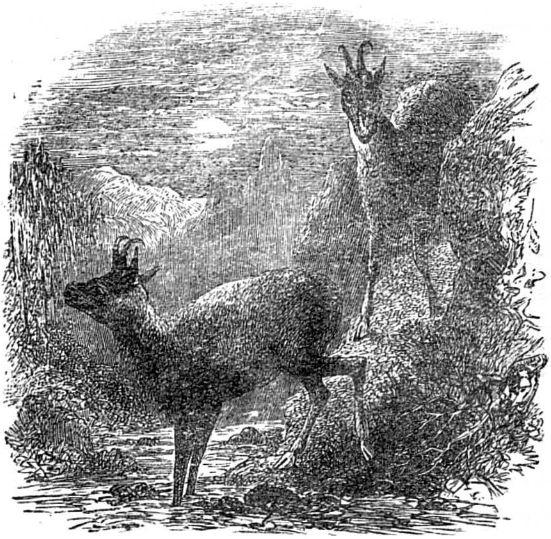


FIG. 14.—CHAMOIS.

always been more or less protected, and some strange stories are told about the relations of keepers and poachers, especially near the border. Charles Boner, in his delightful volume,[2] relates instances of how keepers shot at poachers on sight, and one in which

[1] A. H. Tubby, *Alpine Journal*, vol. xxv. p. 575.

[2] "Chamois Hunting in the Mountains of Bavaria and in the Tyrol," chap. xxxi.

the latter took a more elaborate revenge. Three of them caught a keeper asleep in a chalet, and made him prisoner before he could grasp his rifle. Two then held him fast while the third beat him with a cudgel till he became insensible. From that state he was roused by a sharp pang. "The men were raising him against the wooden walls of the hut, and extending his legs and arms, were nailing them to the boards. Having no nails, they had cut pointed wooden pegs, which they drove through each hand and foot; and so they left him on the mountain upreared—crucified." There he hung in agony till sunrise, when he once more became insensible. On coming again to life he found himself lying on the grass. His dog, which had been powerless against his assailants, had remained by him till daylight, and then its barks and howls attracted the notice of a lad out with his cows, who had run for help and released the sufferer. Fortunately no nerve or sinew was injured, so that after some weeks the keeper was again able to go about. The story evidently was still waiting for a final paragraph when the man told it to Mr. Boner's informant, for he left off with these words: "As to the three men who crucified me, I have often seen them since in the inn-room and out in the fields. However, should I meet them in the wood or on the mountain in my territory, then I shall do as I have always done yet." Another extract from the same book [1] may give those last words a more definite meaning, though it concerns another keeper, still a young man and only an assistant. He was going along the ridge of a mountain

[1] Chap. xvi.

called the Geidauer Eibel Spitz, and, looking down, saw twenty-three men standing by a hut. He watched them for a long time and thought: "If I could only get a shot at one of them—only at one!" He waited long till at last he saw they were coming up towards him along a little path that led through the latschen.[1] "He allowed them to advance till they were about eighty yards distant, and then let fly at the foremost: he hit him right in the middle of the breast, and the man dropped down on the spot, stone dead." The others halted at once, and as the young fellow lay among the pines he could hear them deliberating what they should do. "Some were for going back, when one of them said it was a shame to think of going away without knowing more about the matter. . . . Come what might, he would go on, and the others might follow if they liked. So with rifle in hand all ready to fire, on he went alone, straight towards the place where K—— was concealed. He let him come on to about sixty paces and fired. The shot turned the fellow quite round on one side; he stopped short and then fell, and when the others saw this they all turned, and were off as fast as they could go." The young man descended by another way, and when reloading his gun he thought, "as there was no knowing what might happen," he would charge one barrel with shot, putting ball into the other. Then he sat down among the bushes, near to where a stream was bridged by a plank, to see whether by chance the poachers were descending by the track into which he had come. After about an hour he heard voices, and then saw several men approaching. It was

[1] A dwarf pine, see p. 268.

getting dark, but he could just make out that they were all armed. So feeling sure they were the same gang, he waited till they were crowded together before crossing the little bridge, and then fired his shot-barrel into the midst of them, wounding one of them severely in the chest. Before they could recover from their consternation at this new and unexpected attack, the young forester slipped away through the bushes, and took another path home. Of course he kept his own counsel for many years, and the poachers never knew who had killed one of their number, crippled another for life, and badly peppered a third.

Notwithstanding poachers and other obstacles to their preservation, chamois are still fairly abundant in the North-eastern Alps. We are told in a volume[1] some forty years more recent than the one just quoted, "Sport in the Alps in the Past and Present," that in the year 1892 no fewer than 8,144 head of chamois were shot in the Austrian Alps—this was more than three-fourths of the "bag" secured in the whole of the chain, which Mr. Baillie-Grohman estimates at about 11,000. He thinks that of late years the number of chamois has increased. Certainly it has in the Salzburg mountains, for instead of being at most 6,500 as it was in 1860, it had risen, when he wrote, to at least 22,000. In a protected district they become less timid. I remember that one day in 1880, when the Pontresina district was a Freiheit, I was wandering with a friend on the Roseg Glacier, and six chamois crossed the ice three or four hundred yards from us, moving deliber-

[1] By W. A. Baillie-Grohman, 1896, see page 21.

ately and often only walking. On our way back, later in the day, we saw a single one, perhaps a member of the same herd, feeding quite unconcernedly on the valley side, about 200 feet above us and as many yards distant. So much had the chamois increased, that a few days before I had seen from the Piz Languard a herd of over twenty—some, like the Irishman's pig, ran about so much that I could not count them—capering in their play about a snowfield on the north side of the mountain, and I have come in sight of from one to four at a time in almost every part of the Alps; but the largest herds, where no close time existed, were one of nine in 1860, near the Viso, one of fifteen in that same Val Roseg in 1867, and one of seventeen near the Col de la Cavale, in Dauphiné in 1862. In the first-named district, on the Col de Cristillan (9,771 feet), I had my nearest view of a chamois. The day was bright, but a rather keen air was coming from the north, so, as the actual summit of the pass is a small gap in a low crest of bare rocks, we sat down on the lee-side of them to take our lunch. We had just finished, the guides were packing up the provisions, and, as it happened, I was standing close to this gap. A slight clattering noise on the other side made me glance in that direction, and in the next instant a full-grown chamois made its appearance. For a moment it stood as if petrified, then, seeming to think retreat more dangerous than advance, it bounded away to its right and went down the rocky slope at a pace creditable to any antelope; our guides yelling and hurling stones, and no doubt anathematising their ill luck at being unarmed.

The chamois is not restricted to the Alps. The izard of the Pyrenees is the same animal, and it is represented in Albania and the Caucasus. The rutting season, when the bucks sometimes fight fiercely, is in November, and the young are born in May or June. Both sexes have horns, and these are about the same length, but with the buck they are slightly thicker at the base, and the "pot-hook" curves more sharply. Eleven inch heads, according to Mr. Baillie-Grohman, are rare; the longest pair known to him measured, over the curve, slightly more than twelve inches.[1] The coat changes colour during the year. In the summer it is greyish ochre brown, but in the winter it becomes black and shaggy, and the hairs have grown to nearly three times their former length. Along the backbone of the males these in winter reach a great length, occasionally nearly 9 inches, and are a glossy black in colour, just tipped with a yellowish white. They are care fully picked out from the skin of the slain animal, and when "bunched together" form the so-called *gems-bart*, or chamois's beard, for which a high price is paid to ornament the hat. The average weight of an adult buck is about 65 lb. avoirdupois, but Mr. Baillie-Grohman mentions one killed in Transylvania in 1891 which actually scaled 123 lb. The chamois is dainty in its food. The sparsely growing *Lepidium alpinum* on "slopes of rocky débris is one of its principal articles of summer and autumn diet, while the equally insignificant-looking *Meum mutellina* is a favourite herb. In the winter, which is a long period of short commons for chamois,

[1] "Sport in the Alps," p. 33.

their food consists of the withered grass they find under the dense branches of arves and pines, and of fibrous lichen, which hangs in long tresses on these trees, under which they also find shelter from snow. Now and again, when exceptionally heavy falls of snow, followed by rain, press these sheltering branches down to the ground, and they become coated with ice, the poor animals are unable to get out and they die from starvation."[1]

The bouquetin, or steinbock (*Capra ibex*), is a larger and much more stoutly built animal than the chamois. Formerly it ranged over most parts of the Alps, but is now confined to a single district. At the end of the seventeenth century they were not rare in the Tyrol; then more than 350 are said to have been in the mountains at the head of the Zillerthal, which was a preserve of the Archbishops of Salzburg, but before that time they had become very rare in Switzerland. De Saussure states that in his time the animal was no longer found in the neighbourhood of Chamonix, though one is said to have been shot on the south side of the Grandes Jorasses so late as 1856.[2] It had already disappeared from the French and most parts of the Italian Alps, and was becoming scarce in the Eastern Graians, when the naturalist Zumstein, about 1821, prevailed on the Italian Government to pass stringent game laws for its protection. A few years after coming to the throne, King Victor Emmanuel, who was an ardent sportsman, acquired the shooting rights of the Cogne district, and made its mountains a

[1] *Id.*, p. 37.
[2] T. W. Hinchliff, "Summer Months among the Alps," p. 207.

place where the bouquetin had no enemies but himself. The keepers are vigilant and the penalties heavy.[1] That for killing one is—or was—6,000 francs and nine years at the galleys. Even to be in possession of any part of the animal is illegal. Should any one find the skeleton of a bouquetin that has been accidentally killed—and avalanches are sometimes fatal to them—he must give up the horns, for which he receives a small reward. One of my

FIG. 14.—BOUQUETIN.

friends picked up a pair upon a glacier near the Grivola. But on his way down he met a *garde-chasse*, who politely required him to give up his treasure, with the result that some weeks after his return he received a document entitling him to be paid the legal sum. The animals increased so much under this strict protection—for there were "fifty-five keepers whose rifles were said to shoot

[1] Baillie-Grohman, *ut supra*, pp. 265–274.

uncommonly straight"—that though the King sometimes killed about fifty bucks in a season, during the later years of his life, there were at the end many more than five hundred bouquetins in these mountains. Still, there sometimes is a little poaching, and horns do find their way out of the country. The late S. W. King[1] tells an amusing story of how he transported a rather good pair of bouquetin's horns, purchased at Cogne, through some of the Italian valleys and across the frontier, by the help of his guide, who was also owner of the mule on which Mrs. King rode. The curve of the horns fitted exactly under the animal's belly, and were effectually concealed beneath her habit when she was on its back. I have a small pair which travelled over the St. Bernard in the "hare pockets" of my shooting-coat; and a very fine pair, which, once belonging to a friend, were sent to him in England from Aosta—somehow. Victor Emmanuel's collection in his hunting-lodge at Sarre, near Aosta, contained at the time of his death, says Mr. Baillie-Grohman,[2] no fewer than 232 pairs of the males' horns and 22 of the females'. The largest of the former measured a little over 30 inches along the curve, and their circumference at the base was not much less than 10 inches. The largest doe's horns (these are always much smaller) were just under 10 inches long and under 5 inches in circumference. The bouquetin is, though much more sturdily built, even more active and sure-footed than the chamois, and at least as keen in

[1] "Italian Valleys of the Alps," p. 337.
[2] *Loc. cit.*, p. 266.

sight, but its sense of smell is believed to be less acute. Their haunts are the same, but they not unfrequently descend from their usual quarters, and the males occasionally "are so far led away as to form *mésalliances* with humble domestic she-goats belonging to the herds of semi-wild beasts that are turned out high up on the Piedmont mountains during the summer, often without any caretaker at all." The offspring can be crossed with the ibex, and experiments were made by King Victor Emmanuel. After his death the hybrids were transferred to Welschtobel in the Grisons and set at liberty. There the aggressive qualities which they had already manifested became so developed that they had to be destroyed, for they attacked inoffensive wayfarers and shepherds in the most ferocious manner, Mr. Baillie-Grohman gives instances of their pugnacity, but says that a small colony of half and three-quarter breds was doing well in the Salzburg *Tännen-Gebirg*. Representative species exist in other mountain regions. There is one in the Pyrenees and in the Sierra Nevada—though some consider these distinct—one in Crete, another in Sinai, Arabia, and parts of Palestine and Upper Egypt, besides three species in the Caucasus and others in the different mountain systems of Asia.[1]

Birds are fairly well represented in the Alps. Whether the largest of them, the Bearded Vulture, or Lämmergeier (*Gypaetus barbatus*), still exists is

[1] Mr. Lydekker regards the Spanish and Caucasian animals as goats rather than true ibexes, admitting only four species of the latter, viz., the Alpine, the Himalayan, the Arabian, and the Abyssinian (Royal Natural History vol. ii., p. 244).

now said to be doubtful; but I feel sure that I saw it once or twice in the earlier years of my mountain climbing. The story of the last known to have met its death in Switzerland is thus related:[1] "Its home was the Canton of the Vallais, where for the space of a quarter of a century it dwelt among the jagged peaks of the Lötschenthal. . . . The inhabitants, whose cats disappeared with a surprising regularity, knew the bird intimately. It was a female of advanced age, as was plain from its almost white underparts, and was familiarly known as 's'alt Wyb' (the Old Woman)." Its mate had been shot in 1862, from which time it had been a lonely widow. "The venerable dame of the Lötschenthal Alps came at last to a lamentable end. She was found dead, above Visp, in February, 1887, beside the corpse of a poisoned fox." But a century ago the bearded vulture was not uncommon,[2] and a scourge to the shepherds. Lambs and kids were often carried away to the eyrie; sheep, goats, and full-grown chamois were not killed with beak and claw, but the bird swooped down on them as they were traversing rocks and buffeted them with its long wings till they were precipitated down the cliffs. Carrion or fresh meat was equally welcome, and the bird's power of swallowing and of digestion were amazing. Tschudi mentions that fragments of a cow's ribs, six inches long, wool and hair, the ribs and the brush of a fox, and the more solid parts of many smaller animals, which are often swal-

[1] W. A. B. Coolidge, *ut supra*, p. 53.

[2] In the seventeenth century they were numerous. An inscription at St. Bartolomeo on the Königssee speaks of one hunter having killed 127 of these birds (Baillie-Grohman, *ut supra*, p. 34).

lowed whole, have been found in this or that specimen. Nor was it safe to leave little children unguarded on the mountains. As the story of Geier-Anni has been so often told, we need only mention that a three-year-old child, while her parents were haymaking on an alp just out of sight, was carried away by a vulture. Fortunately a peasant, while walking in a glen some short distance off, heard the cry of a child, went to see the cause, saw the bird take wing, and rescued the little one hardly the worse for the rough grip and the flight through the air. The golden eagle (*Aquila chrysaetos*) still lingers, though it is becoming very rare. In earlier years I more than once saw it; but usually at a considerable distance. Kites, harriers, falcons are sometimes seen, and hawks are not uncommon; but the ordinary traveller finds it hard to recognise the species when the bird is soaring about in the air.

The raven may be sometimes watched on the wing, or its ill-omened, hoarse croak heard sounding from the crags, and jackdaws are common; but a more welcome sight to the wanderer in the mountains is the Alpine chough (*Pyrrhocorax alpinus*), which is almost identical with the Cornish chough (*P. graculus*), now so rare in England, for the only notable difference is that the former has a yellow instead of a red bill, the legs being red in both. They hang about rocky peaks frequently visited by tourists, such as the Piz Languard or Monte Rosa, to pick up the scraps from their lunch, and are by no means timid, settling on crags only a few yards away from the party, for they know that the man with an ice-axe is harmless and a provider of food. The English species, or variety, is said also to occur, though I think less commonly.

The capercaillie (*Tetrao urogallus*) is the largest of the Alpine game-birds, but it is nearly confined to the northern Tyrol, and keeps to the lower parts of the forests. So also do the Greek partridge (*Perdix Græca*), a close ally of the French partridge, and the hazelgrouse (*Tetrao bonassa*); but the blackcock (*Tetrao tetrix*) ranges up to about 4,000 feet. The ptarmigan (*Lagopus alpinus*), however, is a genuine mountain bird, for its favourite haunts are between the tree-limit and the snowfields. There it is not unfrequently seen singly or in small coveys. Like the Alpine hare, it turns white in winter, and is slow in getting altogether quit of its cold-weather plumage. I once saw an interesting struggle in a hen ptarmigan between the fear of man and the maternal instinct. On my way down from the Sparrenhorn I unexpectedly came round the corner of a rock in front of which she was sunning herself with her brood of small chicks. They toddled off, as best they could, in different directions. She took wing, and went straight away for some twenty yards at full speed. Then I saw her suddenly check in her flight, and almost at once drop on the stone-strewn ground. I stood against the rock perfectly still. Then she began to run in and out, working back towards me, making a slight clucking noise, when now one, now another, of the chicks came running from among the stones to join her. Most of the brood was soon collected, but three or four, as I had noticed, had gone rather apart from the others. Then she began to work in that direction—all this hardly twenty yards away from me—till she had got them also. One, however, to judge by her actions, was still missing, and apparently in search of that she passed out of sight among the boulders. It was quite evident that for a moment the instinct of self-preservation had prevailed, but then the sense of duty asserted itself.

Over other birds we must pass briefly. Owls, among them the eagle owl (*Strix bubo*) and the horned owl (*S. otus*), are said to be not rare, but from their nocturnal habits are rarely seen. Gulls of more than one species are common on the great Alpine lakes, and the black-headed gull—now a winter visitor to St. James's Park and the Thames—remains there for the whole year. In the summer two kinds of tern may be noticed. Herons, coots, and grebes may also be seen, as in England, with other frequenters of the water. The smaller land birds must receive only brief mention. Most of our English species occur, some which are rare with us being comparatively common, together with a few which do not reach our islands. Crows and rooks, jackdaws and magpies, are not wanting; but in the higher mountain valleys the most noteworthy birds are the nutcrackers (*Nucifraga caryocatactes*), which are fairly common—for example, near Zermatt, or in any place where there are many arollas on the cones of which they feed; but it is difficult to get a good sight of them, for they are rather shy birds. The little crossbill is less common, but has similar haunts. "The jay's (*Garrulus glandarius*) harsh cry breaks now and again the stillness of the woods; the white-breasted swift (*Cypselus alpinus*) plies its untiring wing high in the air; and the dipper (*Cinclus aquaticus*), yet more conspicuous with throat and breast of white, sits perched on a boulder by the torrent or darts arrow-like up the stream"; the Alpine accentor (*A. alpinus*), its throat white with crescent spots of black; the stonechat, with its harsh chirp; the snowfinch (*Fringilla nivalis*), the wheatear (*Sylvia œnanthe*), with the common and the black redstart (*S. phœnicurus* and *S. tithys*), enliven the stony tracts above the Alpine pastures. Less common is the little wall-creeper (*Tichodroma muraria*), which I have occasionally had the pleasure of watching. It is rather larger than our tree-creeper, but has much the same habits, except that it takes its exercise on rocks instead of tree-trunks. It is an unusually pretty bird, with its grey head and back, crimson wing coverts, and black-tipped tail and pinion feathers. Larger and still more beautiful is the rose-coloured pastor (*Pastor roseus*), which I once saw on the cliffs of a mountain near the Grande Chartreuse.

Reptiles and amphibia have more representatives than in England. Snakes are commoner on the southern than on the northern side of the chain. I have seen but few, and those generally dead by the roadside. Among them are our common snake (*Natrix torquata*), and the adder, which is represented by more than one species, including the English one (*Pelius berus*). The latter genus is said to be abundant, and in consequence dangerous, on the mountains near Champéry. It is found up to about 7,000 feet, and some of the snakes also go high. The largest that I have seen was creeping on a rough, grassy bank by the roadside between Cezanne and

Oulx, on the descent from the Mont Genèvre Pass. It was over a yard long, and not an English species; but I did not examine it closely, as I saw it was harmless and thought the world wide enough for both of us. The snake-like blindworm (*Anguis fragilis*) is not rare. The active little lizard (*Lacerta agilis*), which occurs in the south of England, is abundant in the warmer districts, and the green lizard (*L. viridis*), is so in some parts. The sunny faces of rough walls are their favourite haunts. Frogs, both *Rana temporaria* and *esculenta*, are common in the lower valleys, the former almost swarming in the marshy places, and a third species (*R. alpina*), is often seen near the mountain tarns, up to about 7,000 feet above sea-level. Toads also are not rare, and an Alpine variety or species is occasionally found at nearly as great an elevation. The bright-green tree-frog (*Hyla arborea*) barely reaches the mountains, and is seen with difficulty because of its habits. I once found it by the Lake of Geneva, near Lausanne. Much more common is the little black salamander (*Salamandra atrata*), which is said to range from about 3,000 to 10,000 feet, and of which some writers have made two species, one all black, the other marked with orange spots on the flank and belly. I have seen it in most parts of the Alps, and quite commonly near Cortina d'Ampezzo (in the Dolomites, 4,048 feet), especially on an evening after rain. Here they were crawling about "a low wall by the roadside, just outside the town, into the crevices of which they scrambled, if disturbed, with a slow, wriggling, awkward gait. Commonly they are from 4 to 6 inches in length, but occasionally may be found about 2 inches longer." The highest position in which I have found one was near the little lakes forming the sources of the Po, about 7,700 feet above the sea. They are clammy, unpleasant-looking creatures, but though they have a bad reputation with the peasants, are quite harmless. The newts (*Triton*) are represented by more species than in England, and sometimes range up to nearly the same elevation as the frogs and toads, but are not likely to attract the attention of the passing traveller.

If we may trust early writers on the Alps, these were formerly haunted by some very formidable reptiles. The Zurich professor, J. J. Scheuchzer, who published his *Itinera Alpina* in 1723, describes and depicts several kinds of dragons. More than one is serpent-like, another has rudimentary legs, a third has suckers of a sort substituted for its right fore-leg, a fourth is quadrupedal, others are winged. In fact, if their zoology were closely studied, they would require almost a chapter to themselves. They survived to quite recent times; for we are given a circumstantial account of how in 1649 a dragon was seen to fly from Mount Pilatus across the clear sky, and another, which, however, was only two ells long, was killed, by aid of sling and stone, in October, 1702, by a brave native of the Val Bregaglia. But they have all vanished, as completely as the Deinosaurians and Pterodactyles, and, unlike them, have "left not a wrack behind," except a number of quaint stories.

Fish abound in the lakes and in some of the mountain streams. One author gives the number of species as forty-seven, and the genus *Salmo* is well represented. The salmon proper (*S. salar*) hardly reaches the mountains. There is, however, a species (*S. lacustris*) which belongs to the Lake of Constance and goes up the Rhine as far as Trons, and another (*S. Marœna*) frequents the great lakes, and may be over 4 lb. in weight. In the Lake of Geneva it goes by the name of *ferrat*. Salmon trout (*Salmo trutta*) inhabit the lakes, and generally go some distance from them up the rivers; specimens weighing from 10 to 12 lb., and occasionally even 30 lb., have been caught in the Lake of Geneva.[1] Trout (*S. fario*) abound in almost every river; one may see men fishing in water which at no great distance has issued from a glacier. They are certainly found in streams nearly 7,000 feet above sea-level. I remember, in my earlier days, seeing a notice at a little inn on the Bernina road, just at the mouth of the Heuthal, with this inscription: "*Zu jeder Zeit frische Forellen.*"[2] The height of thi, spot is fully 6,700 feet, and probably trout may occasionally be found not far below the snow-line, but they run smaller as the habitat gets colder. The larger lakes are well stocked with fish, mostly English species, such as the pike, which, according to Tschudi, ranges up to 3,400 feet, the perch, roach, dace, and the like, and in suitable places eels. I remember a very large and thick one being brought, in 1867, to Caprile, which had been caught in the Lago d'Alleghe (3,320 feet). The burbot (*Lota vulgaris*) is rather plentiful, and much sought after because of its excellent flavour; also there are sundry carp, a small species of which is plentiful in the Lom-

[1] Morell, "Scientific Guide to Switzerland," p. 263.

[2] "Fresh trout always to be had." They were, of course, caught occasionally, and kept alive in a submerged box.

bard Lakes, and is almost as delicate in flavour as the char. It is there called agone, its scientific name being *Cyprinus lariensis.* Some of the smaller kinds of fish are abundant in the warmer lakes, as any one can see. I remember some thirty years ago watching a good many of such fish landed at Desenzano from the Lago di Garda by a very youthful angler, whose apparatus and method of providing himself with bait were equally primitive. Close to him, on the shore, an old woman was on her knees bending over the water to scrub clothes in the usual way. Her back was broad, and its smooth surface was attractive to the flies. When the boy wanted a fresh bait he merely stepped to her side and with a dexterous sweep of his half-closed hand captured one of them, which was promptly impaled on his hook. The process was repeated every few minutes, for the bites were frequent and the bait perishable. Sundry kinds of fresh-water fish used to appear at the *table d'hôte* of inns in the neighbourhood of the larger lakes, but of late years I have seldom seen them, probably because the supply would not equal the demand; perhaps, also, lest they should be disdained as merely home-produce. So in their place sea fish is served, but this is not a change for the better, since, though sent by quick trains and packed in ice, it has acquired something of that flavour which the first Hanoverian king so much missed when he came from the oysters served at Herrenhausen to those brought from the waters of Whitstable or Colchester.

The invertebrate animals of the Alps are so numerous that we can only glance at a few of the more conspicuous forms. Several species of mollusca ascend to a considerable height, though apparently they are less common there than in England. *Bulimus montanus* wanders up to about 6,000 feet, and I remember finding its shells rather abundant on the grassy slopes above Bourg St. Maurice. An Alpine variety of *Helix arbustorum* wanders rather higher—to about 7,000 feet—but the most conspicuous shell in the Alpine regions is *H. pomatia*, though it remains in the warmer regions, not venturing above about 4,000 feet. Below this it is often very abundant, crawling on the vineyard walls and foraging under the bushes. It is found on some of our chalk downs—for example, those above Caterham and at Box Hill—and is supposed to have been introduced by the Romans, with whom it was an item in the *menu*, as it still is in Italy. On the approach of winter the animal closes up its shell by a secretion of carbonate of lime, which at the coming of spring is pushed out. I remember seeing numbers of these doors under a rough hedge by the side of a vineyard on the slopes above Thun.

Few fail to notice the butterflies, which are much more numerous in the Alps than in this country. Nearly all our species are there, with several others, some rare with us being quite common; most of them range rather higher on the southern than on the northern slopes. The beautiful Swallowtail (*Papilio machaon*), which now only lingers in our English fens, is rather abundant up to at least 4,000 feet. Its hardly less beautiful brother (*P. podalirius*), which is not generally admitted into the list of British butterflies, does not ascend so high, and is commoner on the southern side of the watershed. Very handsome also is the Apollo, with its downy white wings, with black spots on the upper pair and broad rings of red on the lower. The larger species (*Parnassius Apollo*), is seldom found much below 3,000 feet and ranges well up to nearly 6,000 feet, while its smaller kinsman, *P. delius*, wanders over a zone beginning and ending about 1,000 feet higher. The "whites" go well into the mountains, the more notable being *Leucophasia sinapis*, the English Wood-white, *Aporia crategi* the Black-veined-white, which are, I think, commoner than with us, and *Pieris Daplidice*, our very rare Bath-White, which I remember to have seen in the Visp-thal, the Brimstone (*Gonepteryx Rhamni*), and the Sulphur butterflies, especially the latter, range up to the higher Alpine pastures. This genus, *Colias*, has at least one more representative than in England, and they are generally abundant. The Painted-lady (*Cynthia cardui*) is said to have been found up to 9,000 feet, and some of the *Vanessæ* range high. I saw the small Tortoise-shell (*V. urticæ*) fluttering about the top of the Grivola (13,030 feet) in company with a blue-bottle fly, but the Camberwell-beauty, though not such a rarity as in our land, does not go above 2,500 feet, at which height I have seen it. The Fritillaries are abundant, and range in suitable places to a considerable height. I believe most of our species occur, but one of them, the Queen-of-Spain (*Argynnis Lathonia*), and another, Weaver's-fritillary (*Melitæa Dia*), to which admission is refused, are not rare. I think the latter does not ascend high; the former, if I mistake not, flew by me, with another species of the same genus, and two of *Erebia*, while

I was seated on the top of the Strahlegg Pass (10,995 feet).

The Coppers (*Lycena*) mount to the highest pastures, and are represented by about three species, one of them being closely allied to the Great Copper (*L. dispar*), now vanished from our fens. It will be long before this genus disappears from the Alps. Representatives of the genus *Polyommatus* which get their scientific name from the under-surface of their wings, are common on the mountains. The Folkestone-blue, *P. Adonis*, and the Chalk-hill-blue, *P. Corydon*, the one so rich, the other so delicate, in colour, are often abundant, and so is the Common-blue *P. Alexis*—or one very like it. For these, especially the last, and the Small-copper *P. Phleas*, puddles in the road, especially if flavoured with ammonia, seem to be curiously attractive. They settle there in dozens, and act as if stupefied, for it would be easy to tread upon them. Our English species of "Ringlets" and "Heaths" are common, and two of them, *Erebia blandina* and *E. Cassiope*, rare mountain butterflies with us, are common on the higher Alpine slopes, the latter one being said to range from 5,600 feet to 8,500 feet, and though it sometimes descends lower it is not likely to be found unless the peaks generally rise above the former limit. *E. blandina* occupies a similar but rather lower zone.

Of the *Sphyngidæ*, the Humming-bird Hawk-moth (*Macroglossa stellatarum*) is extremely abundant in the warmer valleys, but so far as I have seen, both it and its relatives are confined to the regions where the vine can grow, in which also "I have found the Death's-head (*Acherontia atropos*) and the Oleander

(*Chærocampa nerii*). Once, however, I saw a good many caterpillars of *Deilephila euphorbiæ* on the ascent to the Great Scheidegg above Grindelwald, and came upon a fine specimen of *Sphinx convolvuli* dead on a snowfield at the head of the Val Pellice, near the Viso, at a height of about 9,000 feet above the sea."[1] The pretty Burnet-moths are very abundant on pastures up to a height of quite 6,000 feet. Both the common English species may be recognised, and *Anthrocera minos*, which in our islands is almost restricted to the West of Ireland, is anything but rare.

Moths are plentiful enough, till we approach the snow-line, but these we can only mention, as well as beetles. The grass on the upper pastures sometimes seems almost alive with grasshoppers, and they are never silent so long as the sun shines. Towards the margin of the Alps we find two large species, a very conspicuous one, the great green grasshopper (*Acrida viridissima*) and a stouter insect, which throngs the brushwood by the shores of the Italian lakes, making an incessant whirring whistle. These may be found on the southern side of the Alps up to about 4,000 feet above the sea. They will never escape being heard, if not seen; but two allied insects cannot fail to be noticed on the hot roads in the lower valleys. Till disturbed, they are inconspicuous, resembling slightly large and stout grasshoppers of a greyish brown colour, but, when needed, a pair of handsome underwings come from under the coverts, in the one a rich red, in the other a steel-blue in colour, and both bordered with black. Flies are often a pest; the common house-fly used to make the

[1] "Alpine Regions," p. 204.

inns on the Italian side almost intolerable, and it was often bad enough on the northern side of the chain. In the better houses it is now no more a trouble than in England, but out of doors in some parts of the Alps it is an almost intolerable nuisance. It infests the limestone Alps, especially in the month of July, but, so far as my experience goes, is not nearly so troublesome in the regions of crystalline rocks. Outside the houses they are reinforced by kindred which bite as well as tickle. One of these resembles a big blue-bottle; a second, less common, is something like a magnified wasp; and thirdly comes the ubiquitous horse-fly. It is the worst of all, for it acts as though it believed biting to be the purpose for which it was sent into the world, and for that cause it was willing to die. The other two are nervous in proportion to their size, and can thus be more easily kept at bay. Among other pests, the visitor in older days quickly became acquainted with the domestic flea (*Pulex irritans*), and not seldom with the bug (*Cimex lectularius*). Forty or fifty years ago travel in the French and Italian Alps, especially the former, was almost intolerable to those not blessed with an insect-proof skin. The late J. Ormsby[1] thus narrated his experience of the fleas in the Graian Alps: "Without any inordinate vanity, I may say that I am a judge of fleas. I have given them my attention under various circumstances and in various countries. Not to speak of an intimacy with the ordinary flea of the diligence, founded on having travelled many a league in his company, I have spent nights with hardy mountain fleas in Swiss chalets, with desperate *freischütz*, *wildjäger* fleas

[1] "Peaks, Passes, and Glaciers," 2nd series, vol. ii. p. 325.

in the Tyrol, with bold contrabandist fleas on the Spanish Pyrenees, with Arab fleas, restless and lawless, children of the desert, dwellers in tents. But none of these ever impressed me so much as the natives of the Val Savaranche. Equal to any of the others in ferocity and physical vigour, they surpassed them all in instinct. They even give evidence of a kind of mutual dependence, and organisation of labour, which suggests something like a dawning civilisation,—so systematic and well-sustained are their attacks. In the Marmot's Hole [a little auberge] we were knee-deep in them. They crept up our trousers and down our necks until we were saturated with them. They lay in wait for us in dark corners, and sprang upon us suddenly. They clung to us viciously, and bit us at supper, and bit us at breakfast—they bit us sitting and bit us walking. On the mountain side, on the glacier, nay, even on the top of the Grivola, unaffected by the rarefication of the air, unimpressed by the magnificence of the view, there they were, biting away as if they had not broken their fast for twenty-four hours." Graphic, but hardly exaggerated!

Ants are common; I remember, when we were in a boat on the Lake of Lucerne, a great number settling on us which promptly proceeded to shed their wings. A large brown species (*Formica fusca*) makes its mounds, which are sometimes quite a yard high, in the pine forests, and it is found up to some 6,000 feet above sea-level. I had the satisfaction when staying years ago at the Engstlen Alp of taking revenge on the blue-bottle biters, and providing the ants with provender. These pests kept settling on my trousers; through which, if drawn tight, they can bite, and even through flannel coat and shirt. Stunned with a slap, they fell on to the path, up which the ants were constantly passing. A little party of these promptly seized the "jetsam," and notwithstanding its struggles hauled it off to their larder. Mosquitos sometimes make their presence felt in the larger marshy valleys, especially that of the Rhone. They are apt to be a nuisance at Martigny and Vernayaz, and I think are extending their range, for of late years they have adopted a policy of pin-pricks at Sion and Sierre. I once felt their attentions near Zermatt, and another time when sitting under the fir-trees near the upper inn at Arolla—in each case over 5,000 feet above the sea. Spiders are common. One is said to have been found on the summit of the Piz Linard (10,516). Its distant relative, the scorpion, does not cross the Alps. I once saw a specimen at Baveno. It was on a bed at an hotel, in a rather torpid condition.

A tiny insect, *Desoria glacialis*, abounds on the glaciers.[1] If a flat stone be lifted, dozens of these black creatures may be seen kicking about in the little pool of water beneath it, a habit which has got them the soubriquet of the "glacier flea," though they are guiltless of biting. The glacières also have their insect inhabitants. We found three species in a little tunnel in the ice of one in Savoy; two were caddis-flies (*Stenophylax*), the other was an ichneumon (*Paniscus*).[2] In warmer regions, when the night comes on, fireflies may be seen. I have watched them from

[1] De Saussure ("Voyages," §2249) found them on the summit of the Petit Mont Cervin (12,749 feet).

[2] G. F. Browne, "Off the Mill," p. 111.

the train passing through the beautiful glen of the Kuntersweg above Botzen, and they were fairly common at San Martino de Castrozza (4,912 feet) in the Dolomites and near Crissolo in the Po valley, at a slightly lower level. Glow-worms are found in most of the Alpine valleys, but only, so far as I have seen, in the lower parts, as near the Lake of Brienz. In fact, to myself, they are unfamiliar sights, perhaps because one seldom rambles by night, except when making a start before sunrise for a mountain excursion, when we are certainly above their haunts.

CHAPTER XIII

THE ALPS IN RELATION TO MAN

MAN first settled in the Alps long before the dawn of European history. The Palæolithic hunter may have wandered into them in pursuit of game, but though he has left a few relics of his presence in the lowlands, none have occurred, so far as I know, actually within their margin. Probably in his days, or at any rate in the earlier part of them, the snow-line lay considerably below its present limit, and the glaciers extended much farther down the valleys. Even in the Magdalénien, the last of its epochs, according to the division adopted by many authorities, the mammoth still lingered and the reindeer was abundant in Central France. As this implies a temperature considerably lower than it is at the present time, the Alps would hardly tempt the men of that age to establish permanent settlements, so that in all probability they were but rarely visited, and opposed an impassable obstacle to a tribe in search of new lands. An advance was made in Neolithic times, though so far as the evidence goes, in these also no attempt was made to penetrate for any distance into their recesses. But a series of discoveries has been made during the last sixty years, which have shown that in those times permanent settlements were established in many places on the borders of the mountains. The first discovery, which has added a chapter to the history of man in Europe, happened during the winter of 1853–4, at a time when the water of the Lake of Zurich was unusually low. The inhabitants of Ober Meilen, a village on its eastern bank, seized the opportunity of enlarging their vineyards by constructing a wall, in order to add to them a portion of its shore. While doing this they came upon the heads of wooden piles, among which were lying pieces of stag's horn, stone hatchets, and other implements. Such things had, indeed, been previously found, but little notice had hitherto been taken of them. Now, however, M. Æppli, the schoolmaster of Ober Meilen, communicated the news to the *savants* of Zurich, and Dr. F. Keller, who saw their importance, succeeded in awakening the interest of antiquarians. Other lakes now began to yield up their hidden treasures, and it was soon determined that a people had lived by all the Alpine lakes bordering the lowland, whose log-hut villages were built on platforms supported by piles, like those described by Herodotus, five centuries before our era, on Lake Prasias in the south of Roumelia. Fine collections may be seen in the chief museums of Switzerland and other countries, and much has been written about them and their significance. Dr. Monro[1] justly calls this "one of the most remarkable archæological discoveries of the nineteenth century," bringing to light "a singular but long unknown phase of prehistoric civilisation in

[1] "Lake Dwellings of Europe" (1890) (p. 3), in which is given, with many maps, plans, and illustrations, a very full account of the discoveries up to that date.

Europe which found its outcome in the habit of constructing dwellings in lakes, marshes, &c." Most of these interesting sites of pile-supported villages have been found on the margins of lakes, either outside the Alpine chain, such as Neuchatel, Bienne, or Morat, or those which, though penetrating its margin, are more or less in contact with the lowlands; such as Zurich or Constance, Maggiore or Garda, Bourget, the Mond See or the Atter See. They also occur quite away from the mountains, and may be traced down the four great rivers, the Rhone and the Rhine, the Danube and the Po, which radiate from the Alps, and they are in some parts associated with artificial mound-dwellings, more like the crannogs of Ireland. They contain remains of the Stone and Bronze Ages, during which they were, in some cases, continuously inhabited. Objects of iron are comparatively few, and their mode of occurrence leads Dr. Monro to believe[1] that, "with the introduction of that metal into general use in Switzerland, we have a new people who conquered and gave the death-blow to their system of lake-villages. Henceforth these villages fell into decay. . . . In Roman times there remained only the remains of a few stations." The settlements of the pure Stone Age are found only in a limited area of Central Europe, and their greatest development was in the lakes bordering both sides of the Alps, with the exception, perhaps, of the Lac de Bourget, where pile-buildings seem to have been constructed exclusively in the Bronze Age.[2] The remains indicate,

[1] *Ut supra*, p. 545.

[2] So far as I know menhirs or other megalithic remains are rare in the Alps.

even in the earliest settlements, a fairly advanced stage of civilisation. Their owners cultivated flax, fruits, and various kinds of grain. Besides the ordinary instruments of stone, bone, and wood, they could fashion canoes and make pottery, twine, fish-nets, and cloth. In the earlier Stone Age they had domesticated a small species of dog, a small ox, a horned sheep, and the goat. Towards its end they added the horse; and, in the Bronze Age, other and larger breeds of dogs, cattle, and sheep, together with the ass and the pig, the cat and the domestic fowl. The general similarity of objects in ordinary use over so wide an area in Europe seems indicative of considerable intercourse and a common origin of its inhabitants; one or two, indeed, suggest traffic between distant places. In the lake-dwellings stone implements have occasionally been found, formed from three kinds of stone, not one of which is known to occur within the limits of the Alps. These are nephrite, jadeite, and chloromelanite. The last kind is the rarest, only about two hundred of it having been found; of the second, nearly double that number; and of the first, about twice these numbers combined. From the purposes to which they were applied we may infer that they were regarded as valuable and the presence of chips of the nephrite suggests that it, at any rate, was sometimes imported unworked.

The human remains from the earlier Stone Age indicate that a brachycephalic race was then in existence, which gradually gave place to a dolichocephalic one, till the latter prevailed in the full Bronze Age; while the invaders of the Iron Age appear to have been mainly brachycephalic,[1] members of the Celtic

[1] *Ut supra*, p. 537.

race, whose remains are found even on the Alpine passes and who have left their mark on written history.

For some time prior to the year 400 B.C., the Gauls, probably because they needed more room at home, had been pressing on the peoples south of the Alps, and at last came into conflict, as historians tell us, with the growing power of Rome. Legends have gathered round the story of their advance on that city, but there can be little doubt that, with the exception of the Capitol, it was sacked and burnt; and though the Gauls may not have returned scatheless to their mountain fastnesses, they gave trouble for at least another hundred years to the northern part of Italy. Nearly two centuries later the Alps witnessed the passage of a yet more formidable invader, who, however, had come from the opposite side of the Mediterranean. In the year 218 B.C., during the second Punic War, Hannibal led his army from Gaul over one of the Alpine passes, to defeat time after time the Roman forces, to approach the walls of the metropolis, to threaten the existence of the nation, and at last, after a sixteen years' struggle, to retreat, baffled, with no better result than to "point a moral and adorn a tale."[1] By what pass Hannibal crossed has been a fruitful source of controversy. Special correspondents, as Dr. Coolidge observes, were not then in existence.[2] Polybius, who is nearest to being a contemporary authority, for he was born about 204 B.C., was a native of Southern Greece, and had

[1] I, demens, et sævas curre per Alpes, Ut pueris placeas et declamatio fias (Juv., Sat. x. 166).

[2] "The Alps in Nature and History," pp. 56, 156–8.

reached the age of thirty-seven years before he set foot in Italy. But as a preparation for writing his history, which was the work of his later life, he travelled much, in order to understand the general topography of the countries with which it dealt. He makes some rather precise statements about Hannibal's route; but Livy, the other authority, who was not born till 59 B.C., writes much more vaguely. Four passes may be seriously considered as the possible scene of the Carthaginian passage.

The Little St. Bernard found favour with the late W. J. Law.[1] The Mont Cenis, or rather a variation of that pass, called the Little Mont Cenis, was advocated by the late Robert Ellis.[2] W. A. B. Coolidge prefers the Mont Genèvre,[3] and Douglas W. Freshfield[4] strongly advocates the Col de l'Argentière. The last of the four, which leads out of the valley of the Ubaye, a tributary of the Durance, to Cuneo, I have never seen; of the others, the Little St. Bernard seems to me inadmissible, unless we entirely discredit the local topography of Polybius; and the Mont Genèvre appears open to the same objection, so that, although it finds favour with such a great authority as Dr. Coolidge, I still think that, so far as these three are concerned, the Little Mont Cenis has the strongest claims. But I doubt whether the question will be finally settled by anything short of unearthing the

[1] "The Alps of Hannibal" (1866). But this route had been already maintained, as the author mentions in his opening chapter, by De Luc, Wickham and Cramer, and one or two earlier authors.

[2] "Hannibal's Passage of the Alps" (1853), and "An Enquiry into the Ancient Routes between Italy and Gaul" (1867).

[3] "The Alps in Nature and History," chap. viii.

[4] *Alpine Journal*, xi. 267; xiii. 28.

skeleton of an African elephant on the Italian side of the summit.

After Carthage had been utterly crushed, the Romans saw the imperative necessity of strengthening their hold upon the Alps; and early in the first century of the present era they had made themselves masters not only of its passes, but also of at least the low-lands on the farther side. After they had conquered Gaul, and established themselves on the Rhine, the Inn, and the Danube, they left their monuments in the great Alpine valleys, and frequently used some at least of the passes with which Alpine travellers are still familiar. One triumphal arch was erected at Susa, on the joint route of the Mont Genèvre and Mont Cenis, about the year 8 B.C.; another at Aosta (*Augusta Prætoria*) to commemorate the conquest of the Salassi 24 B.C., by Terentius Varro. He rebuilt their devastated town, and Roman work may be seen in the remnants of an amphitheatre, of a possible theatre, of a fairly well-preserved Eastern gate near the arch, and in many parts of the walls. There was a Roman station at Sion, and an interesting collection, found in Canton Valais, of remains from that age may be seen in the Cantonal Museum at Sion, and some fragments of buildings are left at Coire (*Curia Rhœtorum*). A column[1] still stands at St. Pierre on the Great St. Bernard, and the site of a Roman temple to Jupiter Penninus, with inscriptions, coins, &c., has been found on the summit of the pass. On the Little St. Bernard also the foundations of a Roman temple have been recognised,

[1] Said to be a milestone of the date of the younger Constantine (Ball's Guide, Western Alps (1898), p. 429).

together with a column of calc-mica schist supposed to have belonged to it. Still earlier in date are the remains of a stone circle, if these have been rightly identified. Megalithic remains, however, are very rare in the Alps.

Dr. Coolidge[1] has so recently given a succinct account of the "great historical passes" of the Alps, that we may briefly recapitulate his principal conclusions. The southernmost of them is the Col de Tenda (6,145 feet), leading from Cuneo to Ventimiglia. This does not appear in history, though probably well known at an earlier date, till it was crossed by Saracen marauders A.D. 906. A carriage-road was constructed over it between 1779 and 1782. The Col de l'Argentière (6,545 feet), already mentioned, from Cuneo to Barcelonnette, was certainly known to the Romans. The Mont Genèvre (6,083 feet) leads from Briançon to Susa and Turin. This was crossed by Cæsar in 58 B.C., on his way to conquer Gaul, and is mentioned by more than one Roman author. It was a bone of contention between Frank and Lombard about the year A.D. 574, and in later times formed the most direct route from France to Italy. The carriage-road across it was completed in 1806, but "though once in the very first rank of Alpine passes, its historical importance has diminished steadily, and it was practically quite superseded by the Mont Cenis." That pass (6,893 feet) is first distinctly mentioned in 756, when it was crossed by Pippin and was afterwards usually traversed by the Frankish kings on their way to Lombardy. The Hospice on the summit was founded by Louis the

[1] *Ut supra*, chap. viii.

Pious about the year 820, and in 877 Charles the Bald died there. Royal travellers often went that way, but there was only a mule-path over it till Napoleon constructed a carriage-road between 1803 and 1810. The so-called Mont Cenis tunnel, completed in 1870, pierces the watershed seventeen miles to the west of the pass, but before that was made the "Fell railway" (afterwards removed) was constructed on the latter and worked for three years.[1]

The next important pass is the Little St. Bernard (7,179 feet), which "was certainly crossed by Cæsar on his last journey from Gaul to Rome before the outbreak of the Civil War in 49 B.C.," but though probably much used subsequently by Roman officials, it has made little figure in history, though a hospice existed on the summit, and the carriage-road across it was not completed till 1871. The Great St. Bernard (8,111 feet), which has been already mentioned as known to the Romans, was probably frequented even before their age, and never ceased to be one of the chief thoroughfares across the Alps.

A hospice has existed on the summit from about the middle of the ninth century, but it was destroyed by the Saracens and again founded by St. Bernard of Menthon, who died about 1081. The pass was a favourite one with kings and pilgrims on their way to Rome, the last important occasion being when Napoleon, in the month of May, 1800, led his army across it to invade Italy and win the battle of Marengo. Its practical importance has disappeared with the construction of railways, but it is still much

[1] See for an interesting account, E. Whymper, "Scrambles in the Alps," chap. iii.

frequented by Piedmontese labourers in spring and autumn, on the way to find work for the summer in Switzerland. A carriage-road across it was not completed till 1905, and in former days the dangers of a winter crossing were often great. The stories of rescues from storm and snowdrift, effected by the devoted monks and their dogs, are too well known to need recounting; but a grim memorial of what sometimes happened could formerly be seen at the Morgue,[1] close by the convent on the summit. Here the bodies of those who had perished on the journey were laid for identification, the mountain air keeping them from putrifying. In many cases they were never claimed. So a mass of bones covered the floor, and round the walls were ranged a number of corpses, propped up against it; the flesh all shrivelled up and of a dark-brown colour, giving a hideous aspect to the faces.

The two passes at the head of the Saas valley, the Monte Moro (9,390 feet), and the Antrona Pass (9,331 feet), both leading to the Val d'Ossola, were, notwithstanding their elevation, routes much used in the Middle Ages between Switzerland and Italy; the former being chiefly of local value, the latter an important mercantile route. A mule-track, as Dr. Coolidge tells us, had been carried over both by the middle of the fifteenth century; that over the Moro at its beginning; but they have ceased to be generally used since the construction of the Simplon road. Difficulties of access, especially on the southern side, made this pass, though so much lower—for it is only

[1] This is taken from a note which was written in 1856, and the Morgue is no longer open to view.

6,592 feet in height,—less frequented than the others prior to the nineteenth century, but a Hospice existed on it before the middle of the thirteenth; and in the fifteenth and early sixteenth it "was often crossed by the Vallaisans and Swiss, while striving to seize or hold the Val d'Ossola." But the pass afterwards declined in favour till its military advantages—especially that of a broad open valley on either side of the mountainous part—led Napoleon to construct a road on which an army might march in fighting order. Then it at once rose to importance; and the completion, early in 1906, of the tunnel beneath the pass has made it a great international high-road. Its importance will be much augmented by the tunnel under the Lötschen Pass, completed in the present year (1911), which has materially shortened the distance from Bâle to Domo d'Ossola, though the pass itself will in future be but little frequented. The Lötschen Pass (8,842 feet), which crosses a small glacier, was at one time much used, and the Bernese and Valaisans three times fought on its summit. The neighbouring Gemmi Pass (7,641 feet) for long found less favour because of the difficulties of the descent on the southern side. These, however, were to a great extent removed by improvements effected about 1740. But even now it is unsafe to ride down in this direction.

A carriage-road, completed in 1895, crosses the Oberland range at the Grimsel Pass (7,100 feet), ascending the narrow valley of the Aar and passing the wonderful ice-worn rocks around the lonely hospice, and another connects the heads of the Rhone and Reuss valleys over the Furka Pass (7,990 feet); but there is no carriage-road across the main watershed till we reach the St. Gotthard Pass, though there are one or two mule-tracks, of which the Gries Pass (8,098 feet) was often employed in the Middle Ages, notwithstanding that near the top it crosses a small glacier. This, however, is quite flat, and can be easily traversed by beasts of burden. The St. Gotthard (6,936 feet) has long been regarded as one of the most important of the Alpine passes, though before the construction of the carriage-road the lower parts often presented very serious difficulties. Access from the north was impeded by the precipitous shores of the Bay of Uri, and entrance into the grassy basin near Hospenthal was blocked by the Schöllenen gorge. On the other side were three rocky defiles, the middle one, that above Faido, being very formidable. But the St. Gotthard, as Dr. Coolidge states, was in use before the middle of the thirteenth century; and not long after that became, because of its directness, one of the great high-roads for merchandise between Germany and Italy. The carriage-road over the pass was finished in 1830, and the railway tunnel, with the lines leading to it, was opened for traffic in 1881. Its length is 9¼ miles, one entrance being at Göschenen, the other at Airolo, so the traveller by it misses the grand rock scenery of the Schöllenen gorge, though the effect of the triple "corkscrew" tunnels near Wasen, and the two pairs of similar construction in the Faido gorge, add much to the interest of this route. The strategic importance of the St. Gotthard was demonstrated at the end of the eighteenth century, in the war between the Austrians and Russians on the one hand, and the French Republic on the other. After three months' hard fighting the

Austrians had obtained possession of the heads of the valleys of the Reuss and Rhone and captured Zurich. They then awaited the arrival of the Russian forces, but were driven back into the mountains, partly by the energy of Massena, partly by the blunders of the Ministers at Vienna. But they still held a strong position on the Grimsel Pass, from which they were at last driven. Threats and bribery combined—the latter taking the form of a stony tract of land, the Räterichsboden—induced a peasant of Guttannen to lead a detachment of French troops by a difficult route far above the right bank of the Aar till they descended, as it were from the glaciers, close to the summit of the Grimsel Pass,[1] while the main body, under General Gudin, kept the Austrians occupied by a front attack up the Haslithal. Taken by surprise, the latter retreated at full speed into the head of the Rhone valley, from which they speedily crossed into the Ticino valley by the Nufenen Pass. Lecourbe, the French general in the Reuss valley, then pushed them back to the Devil's Bridge. Here they made a desperate stand, after cutting the road in front by blowing up one of the side arches. It was, however, in vain, for the French during the night threw planks across the chasm, and drove their enemies back into the basin of Hospenthal. Here, however, the Austrians found themselves between two fires, for Gudin was now descending from the Furka, so they retired over

[1] In the summer of 1858, while a friend and myself were wandering about some height above the top of the Grimsel Pass, each of us picked up, on the turf below a crag, a round bullet, slightly flattened by impact, which we thought had probably been fired at the French as they were descending.

the Oberalp Pass and were ultimately driven some way down the Vorder-Rheinthal. A little later in the year Suvaroff, coming from the south with one detachment of a Russian army, drove the French, after fierce fighting, from the St. Gotthard Pass, while Rosenberg with another one crossed by the Lukmanier Pass to the head of the Rheinthal, and compelled the French troops to retreat over the Oberalp Pass. Lecourbe evacuated the open basin of Andermatt, blocking the Urnerloch and breaking the roadway at the Devil's Bridge. At this yawning gulf a desperate struggle took place next day, numbers of the Russians falling into the torrent, either disabled by wounds or thrust over the brink by the forward pressure of their friends, till at last Suvaroff turned the position by means of the rocks on the left bank of the torrent, and drove Lecourbe down the valley to the Lake of Lucerne. But it was too late. He found that the latter had carried off all the boats; the precipitous shores of the Bay of Uri were then impracticable for an army, and his foes were daily increasing in strength. Further advance was thus becoming hopeless and delay was dangerous, so Suvaroff led his troops across the Kinzigkulm (6,811 feet) into the head of the Muottathal, then fought his way over the Pragel Pass (5,099 feet), and after vainly endeavouring to drive the French out of the lower part of the Linththal, made his way up the Sernfthal, and over the Panixer Pass (7,897 feet) to Ilanz in the Rhine valley. Here he was comparatively safe, but he was without artillery, which he had been forced to throw into the Lake of Lucerne, and had lost more than a third of his men. So the St. Gotthard Pass, with those leading to it, remained in the hands of the French, and next year Napoleon sent the left wing of his army, 16,000 strong, across it, while he led the main body over the Great St. Bernard. At the present day the Swiss evidently regard the St. Gotthard as one of the keys of their fatherland, for they have constructed strong forts, which they are still augmenting, to command the approach to the southern entrance of the tunnel, and to block the Schöllenen defile, besides fortifying the Furka and the Oberalp roads. Evidently they intend to prevent, if possible, this region again witnessing such a marching and countermarching of alien troops as it did near the beginning of the last century.

The next high-road over the European watershed is the Lukmanier, which leads from Biasca in the Ticino valley to Disentis in the Vorder-Rheinthal. As its highest point is only 6,290 feet, it is the lowest pass between Switzerland and Italy, except the Maloja. It was known so long ago as 965, though the carriage-road was only completed across it in 1877, but it is little used by tourists, as two other routes afford a more direct access from Italy to Eastern Switzerland. The more western of these is the San Bernardino (6,769 feet), which goes from Bellinzona, near the head of the Lago Maggiore, to the upper end of the Hinter-Rhein valley. It was well known, according to Dr. Coolidge, in the Middle Ages, but the difficulties of the Via Mala gorge long kept it, as well as the Splügen, from becoming a favourite route till the completion of the carriage-road in 1823. The scenery is not remarkable, though that of the valley, below the village from which it is named, is attractive, and the actual pass is not much used by travellers. The Splügen also was not greatly frequented till the carriage-road over it was finished (in the same year as the San Bernardino), for the Cardenell gorge, on its southern side, is a second and formidable obstacle, but it also was in use at an early date, and is connected with an important historical episode in the year 1800. General Macdonald was directed by Napoleon to lead a division of the French army across the pass to co-operate in driving the Austrian troops out of Lombardy. He reached the village of Splügen on November 26th, when the early winter snow already lay deep on the pass, and after a prolonged struggle with tourmentes and avalanches, finally reunited his troops at the valley of the Liro, the losses, especially of the rear division in the Cardenell gorge, being very heavy.

Far more important than these, in early days, was the Septimer Pass (7,582 feet), which is now but seldom used, at any rate by the ordinary traveller. It turns off from Bivio-Stalla (the Roman *Bivium*) in the valley of the Oberhalbstein Rhine and descends on Casaccia in the Val Bregaglia, so that before the days of carriage-roads it was the easiest and most direct route from Coire to Chiavenna. According to Dr. Coolidge, it is mentioned in the "Antonine Itinerary" and the Peutinger Table: it was in the earlier Middle Ages the great route from Germany to Italy, and a hospice was first founded on the summit before 831.

Four carriage-roads connect the upper valleys of the Rhine and the Inn; the northernmost, originally completed in 1824, leads by Feldkirch and Bludenz over the Arlberg Pass (5,912 feet), to Landeck on the latter river, at the point where it turns sharply from a northern to an eastern course. It was followed by a railway, completed in 1884, which avoids the last part of the ascent by a tunnel rather more than six miles long. The scenery, though sometimes pretty, is not, on the whole, remarkable. Next comes the road over the Flüela Pass (7,835 feet), leading from Davos to Süs in the Engadine, which was completed in 1867. Of this also the scenery is not striking, though the lonely tarns on the summit are rather impressive, but the descent from Davos to Klosters and along the Landquart to the Rhine is here and there striking. Farther south are the Albula (7,595) and the Julier (7,503 feet) Passes. They diverge at Tiefenkastel on the Oberhalbstein Rhine, which communicated with Thusis and the main valley through the Schyn ravine. As this for long was only accessible to beasts of burden, the carriage-route from Coire was carried across the Lenzer Heide with an ascent and a descent of some 2,000 feet. But a carriage-road was made through this magnificent gorge in 1869, and a railway has since been constructed from Thusis to Samaden, which pierces the watershed by a tunnel $3\frac{3}{4}$ miles in length, and places Pontresina and St. Moritz in direct communication with Boulogne. It follows the carriage-road as far as Preda (5,880), and then, striking off to the S.E., emerges in the Val Bever, a picturesque glen between granitic rocks, which joins the Inn rather below Samaden. The carriage-road continues to climb till it reaches the Albula Pass and descends upon Ponte, four miles below the last-named townlet. The scenery is generally not remarkable, but that on the western side, to a point rather below Preda, is often very attractive.

The Julier Pass, which diverges to the south at Tiefenkastel, is not specially interesting on its western side, but commands from the summit a fine view of the snowy peaks in the Bernina group. Here are two pillars, which have been called Roman milestones, but, according to Dr. Coolidge, they are fragments of a column erected as a boundary-stone, which at some time, near the middle of the sixteenth century, was broken into three pieces, of which one has disappeared and another was set up in the following century as a second column.

The valley of the Inn is also connected with Italy by the Reschen Scheideck, which leads, as already described, from that river, near the noted Finstermünz gorge, to the trough-like valley of the Etsch; also more directly by the Bernina Pass (7,645 feet) from Samaden and Pontresina, by Poschiavo to Tirano in the Valtelline, and by the Maloja Pass (6,256 feet), which follows the Inn to its source and descends the Val Bregaglia to Chiavenna. The former [1] affords magnificent views of the Bernina group, perhaps the most striking being that obtained from the lower part of the ascent near the end of the Morteratsch glacier, at the head of which is seen the noble peak (13,304 feet) from which the group is named. This pass, so far as my experience goes, gives a grander succession of snowy peaks and glaciers than any other one crossed by a carriage-road. The Maloja Pass

[1] An electric railway which keeps near the line of the old mule-track has recently been constructed across it.

on its northern side is much less striking; though the chain of lakes between its summit and St. Moritz is attractive, but the great cliffs forming the head of the Val Bregaglia and the whole of that valley are remarkably fine. The Aprica, the Tonale, and the Stelvio Passes merely connect Italian rivers, the first (3,875 feet) leading from the Valtelline below Tirano to Edolo on the Oglio. It affords, however, some very pretty and rather luxuriant scenery; the second pass (6,181 feet) from the Etsch (or Adige) valley, a little north of Trent, to Edolo, offers many attractions to geologists, but is not otherwise remarkable; while the third—the Stelvio—from the Baths of Bormio to the upper part of the Etsch valley at Spondinig, is noted as the highest carriage-road in the Alps, for its summit is 9,055 feet above the sea. From near that, and during much of the descent, most striking views are obtained of the snowy summit of the Ortler.

Prior to the earlier part of the last century, when a carriage-road (completed in 1825) was constructed by the Austrian Government, the Stelvio was occasionally crossed by armies, but it served as a pass only in case of necessity, for the ascent on the northern side is very steep. In those days the Umbrail Pass, or Wormserjoch, which is both lower (8,242 feet) and easy of access, was preferred as the route from the Vintschgau to the Lake of Como. The Stelvio is wholly in Austrian territory, but the northern slope of the Umbrail belongs to Switzerland, and the Government of that country completed a carriage-road over it in 1901, which joins the Stelvio high up on its southern side.

The Brenner Pass is Nature's gateway through the rampart of the Eastern Alps, and "By far the lowest of all the Alpine passes across the main chain. . . . Reached on either side by straight-drawn valleys leading up to a single ridge, it forms a natural highway over the Alps. Its authentic history starts with the passage (15 B.C.) of Drusus, the stepson of Augustus, on his way to conquer the northern Barbarians, and among them the tribe of the Breones, or Breuni, which gave its name for ever to the pass, and had its name embalmed in the verses of Horace."[1] It was a great highway between Italy and Germany in Roman times, and through it, no doubt, the northern hosts once more streamed southward to conquer their conquerors. It was well known to Charles the Great; was crossed by "the vast majority of the Emperors on their way to or from Rome," being the route followed "on at least one-half of these expeditions."

When the Habsburgers became masters of the Tyrol, the pass, Dr. Coolidge tells us, lost something of its character as an international highway, but the track was improved, and the portion of it which, as usual with the Roman road-makers, avoided the defile between Klausen and Botzen by passing above the cliffs, was abandoned for one down it—the Kuntersweg—which still commemorates the name of its maker or improver, Heinrich Kunter of the latter place. Early in the fifteenth century the rise of the Venetian power threatened to divert traffic from the Brenner to the Ampezzo and the Toblach Passes, as this more eastern route "kept the merchants

[1] W. A. B. Coolidge, *ut supra*, p. 187.

on their journeys for the longest distance on Venetian territory, while it was easily passable for light carriages and carts." So competition, as usual, led to improvement, and the Brenner, in the later part of the fifteenth century was made equally accessible. It was not, however, till 1772, that a modern carriage-road—the first of its kind—was constructed across it; and though its military value to Austria ceased with the loss of her Venetian territory, its commercial was so great that a railway, also the first carried over the Alps, was made and opened for traffic on August 24, 1867.[1] The scenery of the pass, though generally pleasant, is not remarkable, for it affords only passing glimpses of glaciers.

The Brenner Pass descends on the south into the valley of the Eisack, an important tributary of the Etsch or Adige; and the watershed between that river, and the streams flowing to the Danube, is at the head of the Pusterthal, a long trench between the southern and central ranges. So flat is this that the water-parting from the Drave (3,951 feet) is barely perceptible. Almost at the head of the Pusterthal the road to Cortina turns off to the south through a natural gateway in the mountains, and crosses the Ampezzo Pass (5,066 feet) to that town. The peculiar structure of these passes has been noticed in a former chapter.

The Brenner Pass is the last great high-road across the barrier between streams flowing to the Adriatic

[1] I happened to cross the pass by the carriage-road a few days before the opening of the railway, and noticed the great pains taken to protect the new slopes with wattles in a diagonal pattern, and by planting. Again crossing, but by the railway, in 1872, I saw that, except in one or two places where the struggle between man and nature still continued, this had been successful.

and the Black Sea, though there are some passes of minor importance leading from the Gail or Upper Drave to the Italian valleys. Those which cross "the sticks of the eastern fan" are less elevated than the passes over the ranges in the other and more western part of the chain, and though certain of these make some figure in history, we must leave them without further notice for want of space. The great highway of the Semmering, connecting Vienna with Trieste, and now crossed by a railway, is almost beyond the limits of the Alps, as the term is ordinarily understood, and the physical characteristics of this neighbourhood have already been noticed.

The northern range, to the east of the Lake of Constance, is crossed by two rather low passes, over which carriage-roads have been made. The one (3,900 feet) leads from Partenkirch in Bavaria to Zirl in the Innthal, on the western side of Innsbrück; the other, from Jenbach to the east of that city to Wildbad Kreuth and the Tegern See. The latter route skirts the beautiful Achen See (3,066 feet), and almost immediately begins to descend through pine woods to the picturesquely situated bathing establishment, which is frequented by invalids suffering from nervous affections or weakness of the chest. In the lower part of the descent the scenery around the Tegern See, though less Alpine in character, is also very attractive.

From the above notices we can see that the passes which early became important highways (most of them still continue to be, though the construction of railroads and reducing the final ascent by tunnels through the ranges tends to concentrate the traffic) present the following characteristics: a marked interruption in the continuity of the crest; a very gentle gradient in the uppermost part, while the ascent to this from either side either presents no serious difficulties, or such as can be turned without serious difficulty or danger. As a rule, these passes lie well below the snow-line, the few exceptions being in positions where no easier passage could possibly be found in the mountain barrier.

A mountain region is, from its physical features, more or less a divider of nations and a camp of refuge for remnants of earlier races. That is so with the Alps, though the political boundaries do not always correspond with the geographical. Speaking in very general terms, we may say that the people of the northern slopes are Teutonic, of the western French, and of the southern Italian; but the border-line between the first and second is a rather irregular one, and in Switzerland, as might be expected, the two stocks are apt to be mixed. Probably survivors of the Neolithic race may yet be recognised among the Alpine folk, though they are nowhere conspicuous in any one part, like the Basques in the Pyrenees. Politically, the chain is shared between Austria, Bavaria, Switzerland, France, and Italy, and the national do not always correspond with the natural boundaries. Four languages are spoken, German, French, Italian, and Romonsch, of which the last, like the second and third, is a survivor of the Latin tongue, but in which the modifications make it an exceptional variety of the Romance languages. It has segregated into distinct dialects, and forms linguistic islands, if the phrase be permissible. The boundaries of these have been so carefully described by Dr. Coolidge[1] that it will suffice to say that Romonsch (forming two dialects) prevails in the Vorder and parts of the Hinter Rhein valleys; that another variety, called Ladin, is the language of the Engadine or upper valley of the Inn, and that farther east Ladin islets occur in the region of the Dolomites. In the same way there are insulated German- or French-speaking districts, enclosed by or projecting into Italian, and in Switzerland the boundary between these two districts is often an irregular one. French, for example, is spoken in the Rhone valley up to the neighbourhood of Sierre, and German afterwards; it passes beyond the Italian frontier into some of the valleys near Monte Viso, where it is a relic of Vaudois emigrants in days of persecution. In the heads of other valleys, as, for instance, near the Mont Cenis, it indicates former relations with Dauphiné, and the fact that French is the language of the Val d'Aosta,[2] including its tributaries, commemorates the ancient connection of this district with the Duchy of Burgundy. Thus, to use Dr. Coolidge's words, "all the French-speaking districts in Italy are simply relics of former Dauphiné or Savoy supremacy on the wrong side of the Alps."

The Alps, as has been already mentioned, possess but little mineral wealth, and the difficulties of access have for long considerably detracted from the value of that little. For the same reason mountains and

[1] "The Alps in Nature and History," pp. 66, 68.

[2] On my last visit to Aosta (in 1902) it appeared to me that, since the opening of the railway, Italian had gained ground on French.

manufactories were formerly incompatible, but in this respect things are changing. The Alps possess in their torrents an inexhaustible source of energy. This was at first only utilised in the lowlands, and for such purposes as grinding corn or sawing wood. The next great step in advance was applying it, when the need arose for driving great tunnels through lofty ranges, to condense air in order to work the boring-machines, and at the same time improve ventilation; but advances in the application of electricity opened a new and rapidly expanding field for the employment of water-power. Mills and factories, thus worked, are extending up the larger valleys, especially in Switzerland, and this country bids fair to become a centre of industries, which will continue to prosper when the coal-fields of Great Britain are exhausted. To squander its national capital is, for Switzerland, almost impossible, so long as its snow-fields and glaciers endure. This is equally true of other parts of the Alps; but, in the case of that country, its geographical position is favourable, perhaps exceptionally, to the importation of raw fabrics and the distribution of manufactured goods.

Still, though factories may sometimes be seen in mountain glens, though light railways cross passes and ascend to points of view not far below the snow-line, though country villages are lighted by electricity, agriculture, in a somewhat wide sense of the word, is the main occupation of the inhabitants of the Alps. The subject has already been mentioned in the chapter dealing with their vegetation; but something must be added in reference to the arrangements for securing the benefits of their higher pastures.

These have been recently so fully described by Dr. W. A. B. Coolidge, with a knowledge and experience so far exceeding that of any other Englishman, as to render needless more than a very brief summary. The mountain slopes, near or between the upper margin of the pine forests and the stony wastes immediately below the zone of eternal snow, form the pasture region, the alps, as they are called by

FIG. 16.—CHALET VILLAGE, WITH THE SASSO DI PELMO, DOLOMITES.

the Swiss,[1] which have given their name to the chain as a whole. The lower part is mown in the summer and the short hay is stored for winter fodder; but, as the grass grows quickly, it is grazed in the spring and autumn. On these slopes huts are built in convenient positions and at different altitudes, so as to

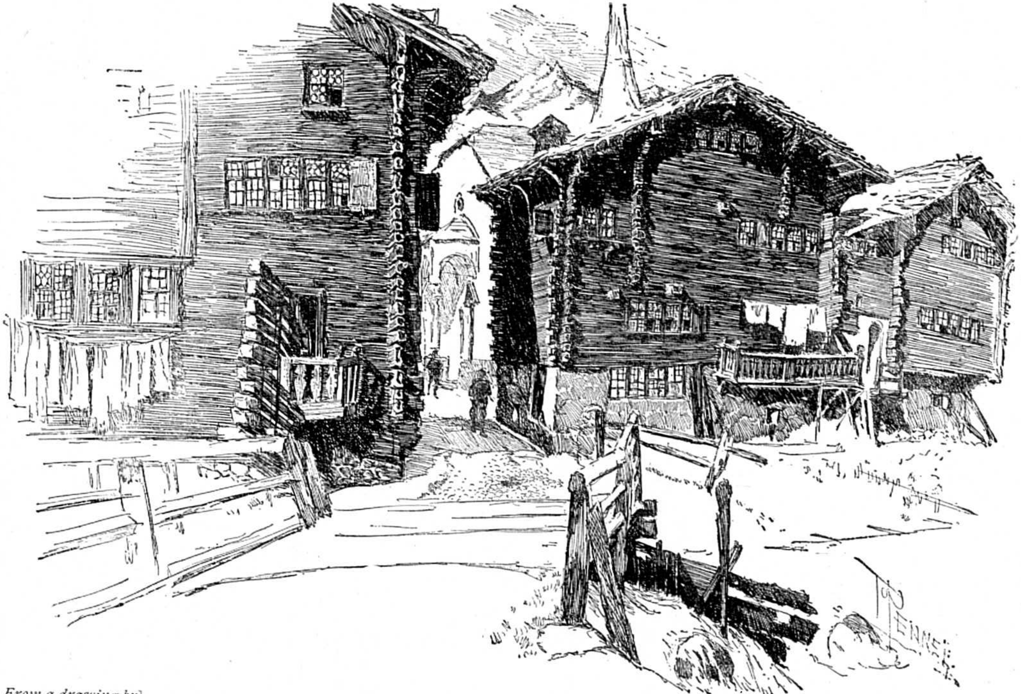
[1] In the Tyrol they are called "alm"; in the French-speaking districts the term "montagne" is often used.

divide the whole region into three, or occasionally four, strips. The lowest cluster of huts will be between 5,000 and 6,000 feet above sea-level ; the highest more than 7,000 feet, and, in the southern districts, even over 8,000 feet.[1] In the spring the cattle are driven up to the lowest group, then to the next one, and so to the highest, at which they spend part of July and August—barely a month—and then descend in like way. The milk is daily made into cheeses, which are at the end of the season divided according to certain rules, for in many cases the herd is made up of cows belonging to several owners. One form of chalet is used for storing the cheese, another for sheltering the cattle in bad weather, and in a third the herdsmen, often three in number—two men of middle age and one still quite young—live and sleep, in surroundings which would make the home of an English peasant seem luxurious. But where the herd is large, more helpers are needed ; sometimes, also, women and even children accompany the men. Hay is often their bed, and it is far the cleaner couch, for though water is generally plentiful, little is expended in washing linen or person. They seldom taste meat or wine ; they bring up a little black bread on occasional visits to the village below, and live chiefly on the products of the milk. After the first curd has been removed from the cheese-pot, some more rennet is added and the cauldron again boiled up. That produces a second curd, called in some places *serré*, or *serac*. This, which tastes like a very inferior cream cheese, is their principal food.

[1] The Upper Pousset huts above Cogne are 8,389 feet above sea-level.

The mode of living is rough, hard, and sometimes even squalid; but it is a healthy one, and the Alpine peasant, cut off from newspapers, books, or pastimes, and with occasional intervals of enforced idleness, acquires, though indefatigable when necessary, the art of doing nothing at all with entire contentment. The traveller, detained by bad weather in some mountain bivouac, finds time hang heavy on his hands, but his guides and porters seem able to while it away by an alternation of sleep and tobacco.

The inhabitants of the Alps, as might be expected from the geographical conditions, are not of one stock. The people in the mountains of Dauphiné, in the days when I was familiar with them, had an ill-nourished aspect. That, however, improved on going northward, the Savoyards being the best. The Tyrolese are better looking than the Swiss, who cannot be called handsome; but both these Alpine folk are a sturdy race, and some of their men are finely developed. The women work as hard as the other sex, and in consequence quickly lose the bloom of youth. They share with them labour in the field and the carriage of burdens. It is astonishing to see how large a bundle of hay a woman can bear upon her head and shoulders, and in some districts a female porter is found more easily than a male to carry one's baggage; not, I think, because the men consider the work derogatory, but because they have other which is more insistent. When, however, porters are much in request, it is surprising to observe what weights these men can carry up and down mountain paths. A few years ago my companion and I had engaged a porter to carry the belongings of the two from the inn by the Lago Ritom down to Airolo, and these, as we thought, made a reasonably full load. To our surprise he asked if he might also take a bag—by no means a little one—from an over-heavy lot in charge of a friend. And the two carried their loads apparently without much effort. But men thus occupied, as our Chamonix guide told us, generally break down almost before reaching middle-life. Even the children begin, at an early age, to carry their little "hottes," often by no means empty, on their backs. Some of the poorest are sent out daily, during the warmer weather, to watch cattle or goats as they feed. The latter, for the most part, are driven to places on the mountain which are too stony to be satisfactory pasturage for cattle, where they contrive to pick up a sufficient sustenance from the coarser sorts of grasses and all kinds of young shoots. One or two lads, often clad in the raggedest of garments, have the goats in charge, leading them out in the early morning, and not returning till the sun is low in the evening. A long string of these goats used to come ambling past the hotel at the entrance of the Val Piora every morning, and late in the afternoon retraced its steps to the main valley. The little herd-boy's chief duties seem to be shouting or aiming an admonitory stone at some goat inclined to stray into forbidden spots or too far away from its fellows. On the homeward journey no guidance is needed; and it is a curious sight to watch the goats, as they pass along a village street, dropping by twos and threes out of the ranks and turning off to their own quarters. In most parts of Switzerland and the Tyrol sheep are less common than goats, but on the French and



From a drawing by] [*Mr. Joseph Pennell.*

28. A STREET IN ZERMATT.

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Italian Alps they are more abundant, especially in the summer, when great herds are driven up from the hot lowlands to enjoy the cool air and abundant grass of the higher Alps. Sometimes the animals are conducted across a glacier, which affords an easy passage, and left on some craggy pastures well insulated by snow-fields, until they are driven back in the autumn. A few may have perished, but the excellent condition of the others is a sufficient compensation. During the winter the cattle and other animals must be kept in the villages, and stall-fed. The lower stage of a house is often devoted to this purpose, the living-rooms being approached by an outside staircase; in others there is a separate building. The hay also is stored in chalets, which are frequently raised on low stone pillars to secure the contents from damp.

When forests are abundant, as in most parts of the Swiss Alps and the Tyrol, the buildings are generally constructed of wood, with, perhaps, the exception of the roof, which is often formed of stone slabs, sometimes kept in place by more solid blocks secured by ropes. The irregular outlines and ruddy brown colouring of the better class make them picturesque objects, so that the narrow street of even a mountain village is very attractive to the artist. The Oberland, on the whole, affords the best examples, which are sometimes ornamented with carving and bear quaint inscriptions, generally with a religious tone, some of them being quite three centuries old. Many of these have been photographed by Mr. Walter Larden,[1] and it is to be hoped that his intention of

[1] Author of that attractive book "Recollections of an Old Mountaineer" (1910).

publishing a selection of them will be carried out. In the French and Italian Alps, where forests are rarer (the comparative scarcity of which often impairs the scenery of Dauphiné),[1] the buildings are of rough stone, and the utmost attempt at ornamentation is a coat of coarse plaster, afterwards whitewashed. But, putting aside a very few instances in the larger valleys, buildings of any architectural merit are rare in the Alps, though the quaint, metal-covered cupolas or slender spires of some of the village churches in the Tyrol are not unattractive, and the wooden bridges protected with galleries in many districts, together with occasional ruined castles, not seldom gratify an artist making a tour, like Dr. Syntax, in search of the picturesque. On the Italian side the tall Romanesque campaniles, though plain almost to severity, are not without attractions; here and there in Dauphiné, as at Neuvache in the Val Clairée and Ville de Val Louise, a really ornamental church nestles quite in the heart of the mountains; but in most parts of Savoy and Switzerland the religious buildings have few attractions. That is not surprising, for money has always been scarce, and the more prosperous parts of the latter country are, with few exceptions, strictly Protestant; those of that creed in the Alpine regions generally occupying the more productive parts, and in the whole country outnumbering the Roman Catholics in the proportion of nearly three to two. In the rest of the Alps, though the descendants of the Vaudois still hold their own in the part of Dauphiné where Felix Neff laboured, and in the Piedmontese valleys,

[1] So scarce is fuel in these mountains that the dung of cattle is dried on the chalet walls for this purpose.

which were the goal of Henri Arnaud and his valiant followers, the great majority belong to the Roman communion; and among the Tyrolese the existence of a devout religious feeling is made obvious, even to the passing traveller, not only by the numerous wayside crosses and shrines, but also by the demeanour of the people.

CHAPTER XIV

FIFTY YEARS OF CHANGE

TRAVELLING in the Alps was a very different matter half a century ago from what it is at the present day. I saw them for the first time in 1856, when I took a small reading party, during the Long Vacation after my degree, to Lausanne. We spent part of the time in that town, another part at Ouchy on the shore of Lake Leman, and an intervening week in a visit to Chamonix and the Great St. Bernard. With one of them I went from London to Bâle, through Belgium and up the Rhine. The first part of the journey was uncomfortable enough. We had a rough crossing from Dover to Ostend, and arrived too late for the through train to Cologne. In consequence of that, we did this journey in a jerky fashion. We had a halt at Ostend, a long one at Ghent, where we saw something of the town, another long one for part of the night at Aachen, and finally reached Cologne early in the morning, nearly eighteen hours late. It was a pleasant change to a steamer on the Rhine, after a look at the city and the cathedral, which was still not much advanced from the incomplete stage in which it had so long remained, and the scenery of the historic river did much to banish fatigue; though bed at Coblenz was welcome after being two days and a half without undressing. Another day took us to Mainz. The next, by railway, after crossing the Rhine from Ludwigshafen to Mannheim, brought us to Bâle, where we arrived in the evening. Thence we had to proceed by diligence. The regular vehicle was already full, so we were sent on by what was called a supplement—that meant being turned out, at the end of every stage, into a fresh carriage. Sometimes this was comfortable—we started in a small omnibus—sometimes much the reverse. For one stage six persons were crowded into a chaise where there was none too much room for four, and sensation gradually departed from our tightly-locked legs. But the dawn after an almost sleepless night was pleasant. We gladly escaped from the carriage as it toiled up the slopes of the Jura towards the Pierre Pertuis. I shall never forget the fresh sweet morning air, the meadow flowers, the peasants with their scythes, jodelling as they walked—the first time we had heard those strange sounds, so musical in the distance. After we had reached the highest point on the road, a drive through beautiful rock and forest scenery brought us down to Bienne, where, after a welcome breakfast, we were taken to a steamer, which carried us along the two lakes (connected by a canal) to Yverdun on Lake Neuchatel, at a pace which, though more leisurely than the train, gave better opportunity of admiring the views. From Yverdun to Lausanne was one of the few bits of railway which had as yet been made in Switzerland, and by this we arrived at our journey's end soon after midday.

At that time a railway from Lausanne to Geneva was in process of construction, but as only a part of it had been completed, steamers were the only means of travelling from one end of Lake Leman to the other. From Geneva we went by diligence to Chamonix, the latter part, from Sallanches, in light carriages, called *char-à-bancs,* which held four besides the driver. That mountain village was still a small place, with inns of only moderate size, if compared with the palatial structures of modern times; and even the mountains were not exactly in their present condition, for the Glacier des Bois then came down to the level of the Arve valley, and the Glacier des Bossons also descended considerably lower than now. We crossed the Mer de Glace from the Montenvers to the Chapeau, and thus obtained our first ideas of glacial phenomena, and on the following morning ascended the Brévent, where a fine day enabled us to appreciate the majesty of the "Monarch of Mountains." Thence we walked over the Tête Noir to Martigny, and from it made an excursion to the Great St. Bernard; afterwards travelling in a diligence down the Rhone valley to Villeneuve. On my return to England from Lausanne I went by Fribourg and Bern, preferring a sight of these two old towns and another view of the Rhine to a journey from Pontarlier across France. One diligence took me to Fribourg, another to Bern, and a third to Bâle, from which I returned as I had come.

My next journey was in 1858, when we got by rail as far as Zurich, and had a long tour through Switzerland, walking over the Rigi to Lucerne, then by the St. Gotthard road, to Andermatt, and over the Furka to the Grimsel, from which the Strahlegg Pass took us for the first time into the heart of the ice-world. After some more wanderings in the Oberland, on both sides of the range, we made our way to Zermatt and crossed the New Weissthor to the Val Anzasca and the Italian Lakes, returning, after visiting Milan, Verona, and Venice, by the Simplon. At that time no railways had advanced anywhere into the mountain zone, and hardly any carriage-roads, except across the great passes, such as the Simplon and the St. Gotthard. As I did not visit the Tyrol till 1867 I cannot speak of its roads from personal knowledge before that date, but they were even then few in number, for Botzen was connected with Cortina d'Ampezzo only by horse-tracks on the southern side of the Dolomites. I visited Dauphiné for the first time in 1860, when there was already an excellent carriage-road from Grenoble to Briançon over the Lautaret Pass and another from the latter town down the valley of the Durance, but in the rest of that mountain-land there was nothing better than a mule-path.

In fact, at the end of the sixth decade of the last century, those who could not ride or walk, had to content themselves with such glimpses of the Alps as could be obtained from a few high-roads. Since then the number of these has been much increased; carriages can now be taken up many of the principal valleys and over sundry passes, such as the Great St. Bernard, the Grimsel, the Furka, and the Oberalp, which, in 1858, could only be traversed by mules. Railways also now not only link all the principal towns to the rest of Europe, but have ascended some of the larger valleys and even pierced the ranges. In 1863 I visited the works at both ends of the so-called

Mont Cenis tunnel. On the northern side they had penetrated the dark schistose rock for a distance of nearly 1,650 yards, on the southern of about 1,200 yards. The tunnel was opened in 1871. Then came the St. Gotthard. Up to 1865 Flüelen was inaccessible to carriages. The Axenstrasse road was then completed, and the railway was begun seven years later. In 1878, I remember that it stopped at Göschenen on one side and at Biasca on the other. It was then carried to Airolo, and the tunnel was completed in 1880. Railways also were constructed on both sides of the Lake of Geneva, one on the Swiss, the other on the new French territory, effecting a junction at St. Maurice. The former was extended in sections up the Rhone valley to Sion, Sierre, and Visp, until, in 1906, the great tunnel under the Simplon Pass was completed, thus affording an alternative route from Bâle to Milan, and placing those parts of France and Germany which border on Switzerland in more direct communication with the Mediterranean and the Suez Canal. But to reach the mouth of the Simplon tunnel from Bâle, or any other point in connection with Western Germany, entails a considerable detour in avoiding the lower buttresses of the Alps; trains from the north joining the Rhone valley railway at Lausanne or Vevey. The route has now been shortened by a railway up the Kander valley from the Lake of Thun, which, near the foot of the noted Gemmi Pass, diverges into the Gasterenthal, pierces the Oberland range, and descends the Lötschenthal to the valley of the Rhone below Visp. A glance at a map of Switzerland and the adjacent Alps shows lines of railways, following valleys to their heads, and giving access to Alpine centres, like Zermatt, or Grindelwald, or Chamonix. The Albula Pass has been tunnelled, the Bernina crossed by a light railway, and the same process of penetration has been extended to the Tyrolese, the French, and the Italian Alps. In 1873 I crossed the Arlberg Pass in a diligence; in 1887 a railway, with the usual summit tunnel, took us from Landeck to Zurich. Aosta is in railway communication with Turin; and the principal places in the French Alps are, or soon will be, linked on to the main railway system. To mention only the additions to these means of access, which, during the last thirty years have been carried out in various parts of the Alpine chain, would be to write a tedious catalogue, so it may suffice to say that mountain railways have been constructed to favourite points of view, like Pilatus, or the Rigi (from opposite sides). You can be hauled or pulled up to pleasant resting places, such as Mürren, the Schynige Platte, the Monte Salvatore and Monte Generoso; you can travel over the Klein Scheidegg from Lauterbrunnen to Grindelwald, and changing trains at the first place, can seat yourself in a carriage on the electric rack-and-pinion "Jungfrau railway," commenced in 1897, and proceed to appreciate the scenery of the High Alps by burrowing like a mole into the crags of the Eiger. Mounting at first in the open over pastures, the train halts (I quote Baedeker, one of the most accurate of guide books), after a short tunnel, at "the Eiger Glacier Station (7,640 feet). Restaurant with veranda, D. 4 fr., in a scene of wild magnificence." A little way beyond this the train disappears into the heart of the mountains, arriving after $2\frac{3}{4}$ miles at "Station Eigerwand (9,405 feet; buffet), with a terrace cut out of the rock, affording a view of the Lake of Thun and a large portion of N. Switzerland. Hence the railway tunnel is carried on to the ($3\frac{1}{2}$ miles) Eismeer Station (10,345 feet; Restaurant, with post-office, and Zeiss telescope) on the S.E. side of the Eiger, about 130 feet above the crevassed Upper Grindelwald-Fiescher Glacier, with a limited but very fine view of the Wetterhörner, Schreckhörner, Fiescherhörner, Mönchjoch, &c." The line is now being carried on to the Jungfrau Joch (11,140 feet), which is $5\frac{1}{2}$ miles farther, where the visitor will ascend to the Terminus Jungfrau (13,428 feet), from which he will be duly hauled by a lift up the remaining 240 feet to the summit of the mountain. Much, no doubt, is gained by these facilities of access, but a good deal is also lost. It is an advantage, with few if any drawbacks, to be saved long journeys, often hot, dusty, uncomfortable, and toilsome, up almost level valleys, trench-like in form, such as that of the Rhone from Villeneuve to Brieg; valleys marshy and sometimes unsavoury; haunts of flies by day and mosquitoes by night; where the high shoulders of the mountains prevent us, as a rule, from obtaining more than the merest glimpses of the glaciers and snow-peaks by which they are crowned. Here and there perhaps, some snow-clad monarch is seen up a side valley, or a waterfall plunges grandly down a crag from an upland glen, but these interludes are generally brief, and no one who has been compelled to ensconce himself in the *intérieur* of a diligence will ever care to repeat the process if it can be avoided. A carriage was much more pleasant, but that mode of conveyance was costly for the solitary traveller, and did not enable him to escape the heat, dust, and other discomforts.

A flat landscape, like the bed of the Rhone Valley, suffers no appreciable injury from the presence of a railway, and the most enthusiastic of pedestrians willingly avails himself of one of its carriages, till it deposits him, in a thankful frame of mind, at the opening of the valley which leads to his favourite mountain "centre." But in many of these valleys a railway is a serious blemish to the scenery and far less of an advantage to the traveller. Even the St. Gotthard may serve as an instance. The lower part of the Reuss Valley from Flüelen to Erstfeld is no doubt flat enough; nevertheless its fields, orchards, and copses possess a charm of their own, while in front the Bristenstock rises in a grand pyramid of crags flecked with snow. We lose something of this from the train, though perhaps it is scenery which is more enjoyable from a carriage than on foot. Still, we have not more than two leagues of this, for immediately beyond Erstfeld the road begins its long ascent. For the next eighteen miles, though we see little of snow-peaks or glaciers, the narrow valley, in places almost a gorge, with its huge enclosing crags, its foreground of ice-worn hummocks and scattered boulders, among which bushes twine and dark pines cast their shadows, affords scenery of exceptional grandeur—scenery through which, unless one has lingered over it more than once, it is a great loss to be hurried. I have several times used the railway, and that thankfully, when I wished to save time in an examination of some part of the valley, or when bound for a place either across or far beyond the Alps, but have always felt that I had to set a loss against the gain. Sometimes, no doubt, we get from the railway a view, only to be obtained from it, of some gorge at the bottom of which either the Reuss itself is roaring, or a tributary torrent, as at the Pfaffensprung, is leaping down, but even that is only a momentary glimpse, ended by a plunge, often instantaneous, into a tunnel. At Göschenen the train disappears altogether from the light of day, to which it does not return till, after a subterranean journey of 9¼ miles, it emerges at Airolo, on the more sunny bed of the Ticino valley. Thus the railway traveller misses the grandest scene in the glen of the Reuss, that near the Devil's Bridge, as noted in history as it is in legend. Unhappily, the slender old arch, to which that name belonged, has now collapsed into the torrent, which, when the carriage-road was constructed, was spanned by one much more safe but far less picturesque. Still, the grandeur of the neighbouring rock scenery remains unchanged, while the contrast between the crag-closed glen at one end of the "Hole of Uri" and the green meadows around Andermatt at the other is so abrupt as to be almost startling. This, with not a little of the rest, is altogether missed. Corkscrew tunnels are triumphs of engineering, but afford no more view than the bottom of a mine, and we burrow through three of them near Wasen. The loss on the southern side of the pass is hardly less. From Airolo to Rodi-Fiesso the valley is generally open, but the scenery, except for one or two waterfalls, is not remarkable, and at the one exception to this rule—the short and rocky gorge of Stalvedro—the railway plunges into a tunnel. Some of the finest views in the noted gorge of Faido are lost by the railway traveller, who gets but rare glimpses of the narrow glen down which the torrent leaps, for he is often underground, and is carried from a higher to a lower level by a pair of corkscrew tunnels. I have been several times through this part of the valley by rail, by diligence, and on foot, and do not hesitate to say that while the second, supposing a good place has been secured, is better than the first, the third is far superior to either. The lover of mountain scenery, no less than the geologist who seeks to understand its structure, must be content to go on foot over those four or five miles between the upper and the lower Levantina valley. That also is hardly less true of the shorter Biaschina ravine, between Lavorgo and Giornico, where also there are two spiral tunnels, one below the other, neither of them much less than a mile in length. But beyond the latter place, though the richness of vegetation, as is so frequent in the southern valleys, begins to soften the stern grandeur of the mountains, the traveller by train in summer-time realises that to have less of the dust and some protection from the sun is no small advantage.

The Alps have become far more accessible during the last fifty years, and this has entailed many other changes. It has increased the number and altogether altered the style of the hotels in the chief places of resort; it has given the mountaineer fairly well-appointed huts instead of squalid chalets, and the ordinary traveller comfortable inns instead of dirty auberges. Within my knowledge an evolution in all parts—almost a revolution in some—has been in process. This has been so marked that perhaps the younger travellers of the present day will hardly believe in our experiences some fifty years ago. In parts of four summers, from 1860 to 1864, I was walking in the Graian, Tarentaise, Maurienne, and Dauphiné Alps. In all these it was but seldom that we found an inn which could be called even passable. In the last district, perhaps, they were the worst. Fresh meat often could not be obtained; the bread and the wine alike were sour; vermin abounded. To escape them was impossible; they despised insect-powder; they waited with anticipatory appetites in the beds; they leaped or crawled on their prey from unsuspected corners. An old peasant in Dauphiné, quoted by the late Edward Whymper,[1] remarked, "As for fleas, I don't pretend to be different to any one else—*I have them.*" Doubtless he spoke the truth; for, as I am very attractive to these pests, I finished the morning toilette by putting on my socks and boots. Thus keeping feet and ankles bare to the last, I could slaughter singly invaders from the floor. One morning—and the hotel was in some respects better than others—I arrested the careers of four nimble and one slow-moving insects. It was no wonder, for the ordinary way of clearing a table after a meal was to throw on to the floor what was left upon the plates, to be eaten at leisure by the dogs. Thus the bones, with chance dirt, formed an "osseous breccia," as they did in the rock shelters of the Dordogne. Scrubbing-brushes, soap, and hot water were apparently unknown luxuries; dogs ran freely in and out, and even fowls, after their wont, came rambling into the ground-floor rooms, with the natural consequences; so that all things which are lovers of dirt were plentiful. Even in

[1] "Scrambles Amongst the Alps" (1871), p. 38.

Switzerland *Pulex irritans* was by no means rare. He often made his first call in a railway-carriage; sometimes not long after leaving Calais, certainly by the time the Alps were in sight.

In the better inns the beds were usually free, but the lurking foe awaited the unwary in unsuspected corners. I was always careful to prefer a cane-bottom chair to one covered with any plush-like stuff, and to avoid a sofa. In the year 1859 we were obliged to pass the night before climbing a lofty peak at a village in the Vispthal. There was no inn, and the curé was good enough to receive us into his house. Notwithstanding my remonstrances, he insisted on putting me into his own bedroom. He was a rather refined and well-read man, and on shelves in that chamber were Latin and Greek books, with which he was evidently familiar, but other tenants of his couch effectually murdered sleep. Gradually these nuisances have disappeared. In the Tyrol I never found them troublesome, but, as I have said, my experiences east of the Rhine did not begin till 1867. But when I returned to Dauphiné in 1887, after twenty-three years' absence, I noted a marked change. It is true that, as I was running a geological section across this part of the Alps, I did not make my way to such places as La Berarde or Ville de Val Louise, which once merited the epithet *pulicosa;* but all along the high-road from Grenoble to the Mont Genèvre the improvement in the condition of the cottages and the aspect of the people was conspicuous; while at La Grave, where we halted for three or four days to study the relations of the sedimentary and crystalline rocks, we found an inn which, though plain, was clean and satisfactory. Its predecessor twenty years before, though far from reaching the lowest depths, was dirty, uncomfortable, and altogether justified A. W. Moore's remark that "there was nothing stable about it but the smell." At Briançon also, instead of the stuffy and far from clean inn up in the town, where we had suspected something unwholesomely cooked to have been served at dinner, owing to the sickness that attacked each one of us on the following day, we found a spacious and really good hotel down by the railway station, both of which had come into existence since the old days. But in all parts of the Alps, even in Switzerland, where, as I have said, the accommodation was generally satisfactory enough to those who could dispense with luxuries, the changes have been very marked. Small inns have been converted into grand hotels, and half a dozen or more have taken the place of the one which existed half a century ago. It will suffice to give two or three instances, for they will illustrate what has happened in almost every part of the Alps. When the late T. W. Hinchliff[1] crossed the Trift Joch in 1857, Zinal was only a group of chalets. In 1860 J. C. Hawkshaw and I, after crossing the Col Durand, found a newly constructed "log-hut," with two little bedrooms, sweet with fresh pine-wood, no bigger than an ordinary ship's cabin, and a small *salle-à-manger*, in which was a bed to hold a couple. In 1903 there were two commodious hotels, and now, according to my Baedeker of 1909, there are three, making up two hundred beds between them. In 1858 Zermatt had but two hotels—the Monte Rosa, under M. and Mme. Seiler,

[1] "Peaks, Passes, and Glaciers" (1859) p. 126.

From a drawing by] [*Mr. Joseph Pennell.*

29. BEFORE THE HOTEL MONT ROSE, ZERMATT.

To face p. 352.

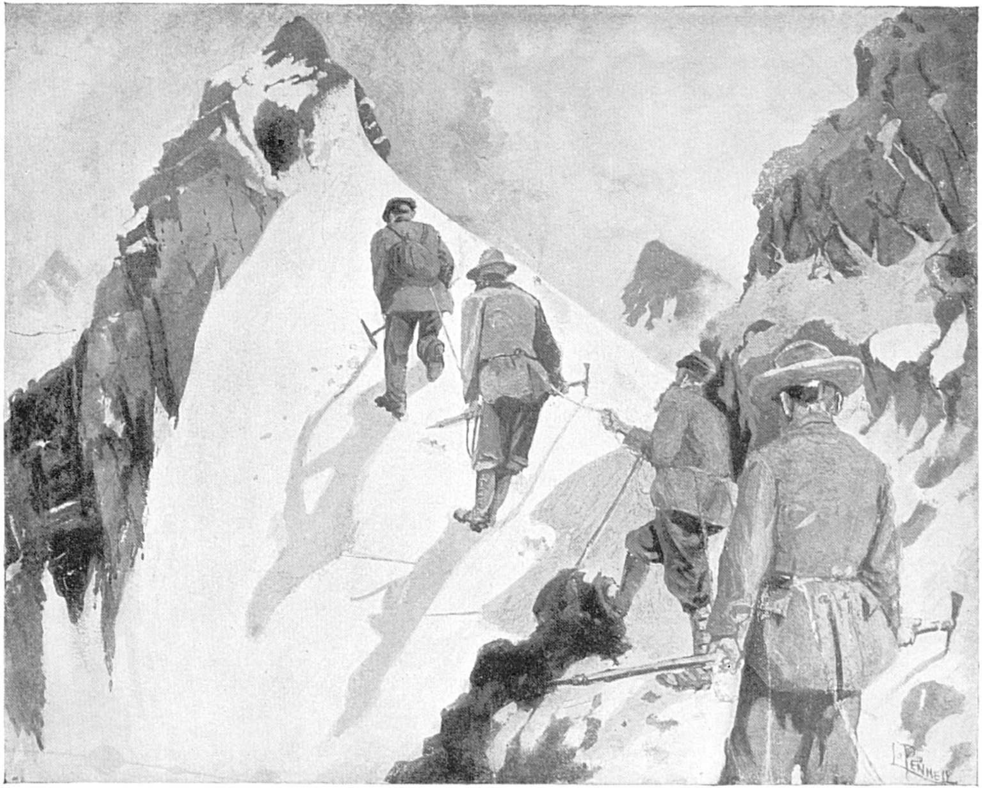
the friends of all Alpine wanderers, and the Mont Cervin, which was slightly the larger of the two. The Riffelalp Hotel did not exist. The Riffelberg was a small and homely place. Needless to speak of the present, when trains disgorge passengers by scores. In 1883 I crossed from the Tosa Falls to the little village of Binn, which is now a rather favourite resort for lowland Swiss who cannot afford expensive *pensions*. There I spent the night in a small but thoroughly comfortable inn. It was spotlessly clean, looking like a new box, as well it might, for, as the landlord proved to me on a subsequent visit, I was the first person who slept there. In the sixties and earlier seventies the inn at Saas Grund was a very rough and none too clean a place. In the first decade of this century I spent three summer holidays there, and found it, when in charge of Mme Paris, all that one could desire. But the transformation of Saas Fee is even greater. I first visited that alp in 1860, which even then had become noted among climbers for its magnificent view. We used to wonder when some one would be adventurous enough to add to the chalet village a little mountain inn, which would make it possible to enjoy the view at all hours in the twenty-four, and would shorten the route to two or three mountain passes, but even in 1874 nothing had been done. Now a considerable village has sprung up, with shops full of such things as visitors are supposed to want, together with four or five big caravanserais, in which nearly as many hundred guests could be accommodated. There may be more now, for I last saw the place in 1907. In 1867 Pontresina was a rather small village stretching along the high-road, and almost divided into two parts. In the lower one were two inns, neither large—the "Krone" and the "Weisses Kreutz," and a very small one, the "Capricorne," just at the beginning of the upper part. When I was last there (and that was before the railway came) in 1893, the road had become an almost continuous street of shops, the village had swelled into a town, and I could not venture, without referring to a Baedeker of that date, to say how many were the hotels, most of them of a size which a quarter of a century earlier would have been deemed gigantic. The prices had risen in proportion. One incident, trifling in itself, served to show how great was the change. From the Morteratsch glacier one can return to Pontresina by either a carriage-road or a pleasant path through the fields. I was coming back one evening, passed in a forgetful moment the right turn-off, and thus had to keep to the road. The weather had been fine, with the usual results. The carriages taking people back from a visit to the glacier soon began to overtake me, and were so numerous that I walked the whole way through a continuous cloud of dust. Samaden, and the other villages higher up the Inn valley, have undergone similar transformations. The Baths of St. Moritz, in 1867, stood alone, or almost so, among the meadows. In 1893 it was a crowded watering-place, full of inns, shops, and other arrangements for easing visitors of any superfluous cash.

The Swiss towns also have been wonderfully altered, and not always for the better. Half a century ago they had extended but little beyond the limits which they had occupied during the later Middle Ages, when, as we may see from Scheuchzer's illustrations,[1] even Bern was restricted, except for a small "fore-gate" on the right bank of the Aar, to that singular peninsula bounded and defended by the river. The mediæval fortifications on the western side, of which traces still remain, had been strengthened by a set of out-works on Vauban's system, but otherwise the seventeenth century had made little change. In 1856 there were not many houses across the Aar, and the town still retained its singularly picturesque and ancient aspect. Architects had not yet come to convert its cathedral into a structure which might have been erected within the last quarter of a century, to smarten up everything that was old, to erect any number of modern public buildings, and to run up new suburbs on the other side of the Aar, connected with the centre of the original city by great iron bridges spanning the river on the same level. In 1856 Lausanne was practically separated from Ouchy. The older part of the former contained many quaint nooks. The restorer had not yet swooped down on its cathedral and its château. Ouchy was hardly more than a waterside village, with one pleasant hotel which faced the lake; and not far from it was a picturesque stone tower with a pyramidal roof, of which I have a sketch. Now Lausanne, expanded far beyond its ancient limits in more than one direction, has crept down the hill to Ouchy, the union with which has been completed by a rope-railway. There are streets where I remember vineyards and gardens in which I used to catch butterflies. The buildings of an hotel have

[1] "Itinera Alpina" (1723), p. 323.

encrusted the Ouchy tower, and windows have been punched through its walls, till it has been as severely "translated" as Bottom the weaver. The lake-side also has been taken in hand; the natural shore-line has been replaced by the walls of quays trespassing upon the water and planted with formal lines of trees. At Zurich, in 1858, I sketched a similar tower, which stood alone a short distance from the Hotel Bellevue. That has disappeared, and the lake has been treated as at Ouchy, with the result of substituting the formal and the "commodious" (to use a favourite epithet of the Georgian era), for the attractive irregularity of garden, shrubbery, and lake margin. Lucerne has been similarly transformed. A large suburb has sprung up around the railway station, non-existent in 1858. The outer walls of the old town, with the quaint towers which defended its northern and upper side, the water-tower on the Reuss and the two old timber-built bridges, one with the grim pictures of the Dance of Death, happily still remain; but new quays have encroached upon the lake, and are linked together by a wide and formal bridge. Sumptuous hotels have sprung up, thronged by the *nouveaux riches* from America and elsewhere; while a crowd of £5-trippers takes its week at "lovely Lucerne" in equally modern caravan-serais. Much of the old has been replaced by new—among it a gateway and part of the town wall, which I sketched in 1858, when it led into a garden or orchard. The site is now covered by big houses—not far, I think, from the Lucernerhof Hotel. All the larger towns have been similarly "translated." Klein Basel now bristles with chimneys, and the old wooden bridge connecting it with the frontier town of Switzerland has disappeared, being replaced by a far grander stone structure, spanning the Rhine with six great arches—more convenient, no doubt, but much less picturesque. In the smaller places the log-built houses are being crowded out by more pretentious modern dwellings, smart with plaster and painted verandas. Only in spots beyond the reach of railways and carriage-roads does something remain of life in the Alps as it used to be fifty years ago. In many respects, as I have already pointed out, the changes have been gains, but there are others where "the old was better." The mountains then were restful; now, in many parts, travel is a "scurry," a railway station a seething crowd. Most travellers then went to the Alps because they loved them. They needed no other attractions than what Nature could provide—flowers and forests, torrents and waterfalls, crags and peaks, glaciers and snow-slopes. Now, whatever may be the grandeur of the scenery, that soon palls on visitors unless they can get their lawn-tennis and their golf, as at an English watering-place. In old times one seldom returned home from the Alps without some addition to the number of one's friends; now the average traveller is unattractive, and a crowded *salle-à-manger*, especially with the much-vaunted separate tables, gives no opportunity for getting so far as acquaintance. The modern hotel is more luxurious, but it is possible to fare over-sumptuously even on an Alpine tour; and being number 144 in a caravanserai is a very different thing to the home-like feeling of an inn which was not too large for host and guest to know something one of another. Old mountaineers look back regretfully to such friends as the Seilers at Zermatt; their beaming faces and cordial clasp of the hand when they met you at the door, the kindly farewell when you reluctantly went away; and if it was over a mountain pass the provision sack always proved to contain some fruit or a little bottle of choicer wine than had been charged in the bill. And there were others, such as old Jean Tairaz at Aosta and Wellig at the Eggischhorn, of whom one will not see the like again.

In the middle of the last century many districts of the Alps were almost unknown to travellers. Not a few of the greater peaks were still unclimbed; many of the more difficult glacier passes had not been attempted. Some of the more remote valleys had been seldom penetrated, at any rate by Englishmen. Thus Alpine travel had the zest of novelty and sometimes the attraction of an exploration. The climber, on gaining the summit of a virgin peak, felt himself to be "the first that ever burst into that silent sea," where the mountain ranges rose in waves of dazzling snow. There was a spice of adventure, as well as of novelty; little commissariat difficulties to be overcome, a certain amount of forethought needed, before plunging into one of the more remote districts. Of some, no maps worthy of the name existed. At our first visit to Dauphiné, in 1860, Bourcet's map (1749–1754) was the only one to be obtained, which, though it was accurate enough for the lower districts, delineated the higher mountains in a semi-pictorial style. But in 1862 Mr. F. F. Tuckett, before making his remarkably successful expedition, received, by the courtesy of the Département de la Guerre at Paris, a



From a drawing by] [*Mr Joseph Pennell.*

30. ON A SNOW ARÊTE.

To face p. 358.

tracing of their unpublished survey of the chief mountain group, a photograph of which, thanks to his kindness, greatly helped us in our subsequent visits. A survey of the mountains enclosing Italy had been published in 1845, under the title "*Le Alpi che cingono l'Italia*," but it was often misleading in the higher parts. In Switzerland things were better, for the Federal survey was at work, and had begun to publish its excellent maps. As a rule, however, travellers depended more on their guides, and often carried only one of the smaller general maps of the country, which did well enough for ordinary purposes. But on the history of Alpine maps it is needless to enlarge; that may be gathered from Dr. Coolidge's comprehensive volume.[1]

The foundation of the English Alpine Club gave a great impulse to mountain climbing, and indirectly helped in making the Alps themselves more accessible. The story of its inception has more than once been told, so I need only say that the idea originated with my late friend, William Mathews, early in 1857, and it rapidly took form with the aid of E. S. Kennedy, whose acquaintance he had made during the summer, so that the Club met for the first time on December 22nd. The first dinner was held on February 2, 1858, when Kennedy was elected Vice-President, and T. W. Hinchliff,[2] Secretary. At the end of March, John Ball, whose knowledge of the Alps was at that time unrivalled, was elected

[1] "The Alps in Nature and History." See especially chap. ix.

[2] Author of "Summer Months Among the Alps" 1857.

President.[1] The list of members originally contained 34 names. It had increased to 124 in 1859, and in 1911 had risen to 711. The new club was not received with open arms by "general society." The "heavy father," in both senses of the term, frowned upon it as inciting to a form of athletics to which in the days of his youth he had never been tempted, and condemned it as a dangerous and purposeless pastime. Newspapers, with the *Times* at their head, censured or scoffed. Whenever an accident did happen—which, fortunately, was but seldom in those early days—letters, more or less fatuous, were indited by persons who had never attempted to go farther than a mule would carry them, and an editor of Murray's "Guide to Switzerland" stated, as "a remarkable fact," that the majority of the persons who had made the ascent of Mont Blanc had been of unsound mind. But the members of the Club took "Let them say" for their motto, and went on climbing and exploring, and unashamedly describing the results in print. They were cautious as well as bold climbers, and thus, in the early days of the Club, accidents, as we have already said, were very rare. Among them also were men who proved that they could write and observe as well as climb, and strove to follow the examples of H. B. de Saussure and J. D. Forbes; so that we heard less and less of the "greased-pole" swarmer or the "criminally reckless" mountaineer. The Club made its first literary essay in 1859, when "Peaks, Passes, and Glaciers; a series

[1] For a summary of particulars, see "The Alps in Nature and History" (W. A. B. Coolidge), pp. 234–37. Also W. Longman, *Alpine Journal*, viii. (Appendix, chap. iv.).

of Excursions by Members of the Alpine Club," was published, under the editorship of John Ball. It was illustrated with chromolithographs, woodcuts, and maps; the last interesting as showing the advances that have been made since that date in the cartography of the Alps. Among the fourteen contributors of articles we find, in addition to the editor, T. W. Hinchliff, E. S. Kennedy, and W. Mathews, Wills (now Sir Alfred), and J. Ll. Davies, both happily still members of the Club, though they have passed the limit of four-score years, together with men of mark in science like Professor J. Tyndall and A. C. Ramsay, afterwards Director-General of the Geological Survey and a knight. Etna was the only mountain included which was not in the Alps, and for it the writer, the late J. F. Hardy, apologises, since it has the further disqualification of not being nearly "13,000 feet high, as the Catanians vainly pretend." The volume includes a first ascent of the Dom, by Davies; of the Grand Combin, then called the Graffeneire, by Mathews; and of the Finsteraarhorn (at any rate by an English party), from the pen of Hardy. The second series of "Peaks, Passes, and Glaciers," in two volumes, appeared in 1862. This not only takes a wider range in the Alps—the Engadine and the Tyrol, the Cottian, the Dauphiné, and the Graian groups, but also includes excursions in the Pyrenees, Norway, and Iceland. It describes first ascents of the Piz Bernina (by English), the Schreckhorn, and the Aletschhorn, the Pelvoux and Monte Viso, the Grand Paradis, and a considerable number of new passes, among which the Eiger Joch is perhaps the most remarkable. Two chapters deal with scientific questions, and tables are given of the heights of peaks and passes, several of which had been reached or crossed for the first time during the three years since the publication of the earlier volume. In March, 1863, appeared the first number of the *Alpine Journal*, which is now in its twenty-sixth volume. Its pages show—and the fact is interesting—how the members of the Club gradually widened their range. The first volume contains accounts of an ascent of El Viejo, an extinct or quiescent volcano in Nicaragua, and a note on Om Shaumer, one of the peaks of the Sinai group. The second volume is almost restricted to the Alps, but records some remarkable successes, with, unfortunately, a larger list of accidents, including that (in 1865) on the Matterhorn. In the latter part is an excellent article on Alpine Dangers, by L. Stephen, than whom there could be no better authority. The third volume, covering only a year (1867), includes the Sierra Nevada, the Eastern Carpathians, and two journeys in the Himalayas. It also describes a winter visit to Grindelwald, during which the Strahlegg and Finsteraar Joch were crossed. The fourth volume includes the Caucasus, when Kasbek and one summit of Elbruz[1] were ascended by C. C. Tucker, H. W. Moore and D. W. Freshfield, and parts of the Himalayas, besides some European mountain districts other than the Alps, gives an account of an ascent of Popocatepetl, and of a winter excursion to Grindelwald in 1866, when the two above-named passes were combined in a single excursion by H. Walker and A. W. Moore, together with a winter visit by the

[1] The other one was climbed in 1874, by F. Gardiner, F. C. Grove, and H. Walker.

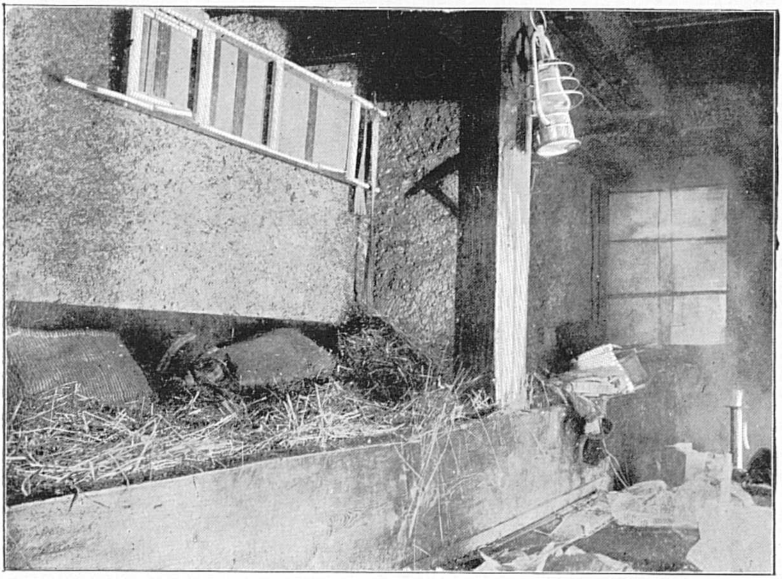
latter to Dauphiné in 1867, when he crossed the Col de Goléon and the much more difficult Brèche de la Meije. Other volumes record successful attacks, dating from 1884, upon the highest peaks and passes of the Caucasus, followed by those on some of the giants in the Himalayas and Karakorams, during the later of which heights above 22,000 feet were reached by W. M. Conway and the Hon. C. G. Bruce, by Dr. and Mrs. Bullock-Workman, and by Dr. T. G. Longstaff. But the Alpine Club might now venture to take for its motto *Quæ regio in terris nostri est non plena laboris.* We need only add that the illustrations in colour soon drop out of the volumes; wood-engravings, among which E. Whymper's work becomes evident, take their place; and in volume x. reproduced photographs begin to appear. These increase in number and excellence, before long replacing wood-engravings, till in the twenty-fourth volume there are no less than eighty-five.

The countries which could claim a share in the Alps soon began to follow the example of England. Austria was the first, its Alpine Club being founded in 1862. The Swiss Alpine Club was founded before the Italian, after the climbing season of 1863. The German Alpine Club dates from 1869, and in 1873 it was fused with the Austrian, under the title "German and Austrian Alpine Club." In the following year the French Alpine Club was instituted, and our example has since been followed on the American continent and at the Antipodes.[1] In the Continental societies,

[1] An admirable sketch of the progress of mountaineering, by C. Pilkington (President, 1896–98) is given in the *Alpine Journal*, vol. xxiv. p. 15 (read on Feb. 4, 1908), and an account of the jubilee of

however, unless I mistake, the standard of qualification as a climber, expected from a candidate for admission, is generally lower than in the English Club. The exertions of the societies having territorial claims in the Alps have done much to smooth the path of visitors. They have established numerous huts, as sleeping-places before making the more important and long expeditions; and some of these are almost luxurious compared with the squalid chalets or shelters under a rock of the old days. They have exercised a salutary influence on the keepers of the smaller mountain inns, thus greatly improving the accommodation; they have made or bettered the tracks leading to points of view within the reach of the ordinary traveller, marking the way to each by signs readily followed, and enabling him to wander at will over the mountain-side without the sense of restraint which is generally felt when a guide is brought for no other purpose than to indicate the way; for in the mountains, though congenial company is best of all, solitude often has its charms. So every one who of late years has visited the places of ordinary resort has good reason for being grateful to the Alpine Club of that country. He will regard with similar feelings the compilers of guide-books, which are now excellent. The first advance was made, under the auspices of the English Alpine Club, by the publication, in 1863, of a Guide to the Western Alps, under the editorship of John Ball, whose knowledge of the chain as a whole was in his day unequalled. It reached a third edition

the Alpine Club, celebrated on December 16 and 17, 1907 will be found at p. 29. It was stated (p. 58) that the number of daughter Clubs was then 166.



31. A MOUNTAIN HUT—OUTSIDE AND INSIDE.

(From photographs by Mrs. Aubrey Le Blond.)

To face p. 364.

in 1870; and a fourth, reconstructed, revised, augmented, and edited by W. A. B. Coolidge, was published in 1898. The volume containing the Central Alps originally appeared in 1864, and has been similarly reconstituted. It has been published in two parts, the first issued in 1907, under the general editorship of A. V. Valentine-Richards, the second in 1911 under that of G. Broke. Ball's volume on the Eastern Alps was not completed till 1868, and has not yet been re-edited. Of other guide-books in English, which cover a wider area than the mountains, the well-known volumes of Murray's Guide must not be forgotten, of which revised and much improved editions have been published from time to time; or the admirable Handbooks of Baedeker, which bear on almost every page marks of the scrupulous care spent in bringing them up to date.

These Clubs have been the means of greatly improving not only the accommodation for travellers, but also the quality of the guides. Fifty years ago, in the unfrequented districts, unless some chance chamois-hunters were available, no one of any value above the snow-line could be obtained. Our attempt upon the Pelvoux in 1860 was foiled, after we had spent two rainy nights and a day under a big boulder, by the utter incapacity of our two local guides. In the Oberland, at Zermatt, and in one or two other places, there were already a few men of real merit. So there were at Chamonix, where for some time past a regularly organised body had existed; which, however, was a forerunner of that variety of trades-union which hampers rather than encourages merit by placing wage before work. Much, however, has been done even with this unprogressive body, and of the credit for that the English Alpine Club may claim no small share. The best guides from that centre and from the Oberland before long began to be employed by some of the more energetic mountaineers beyond the limits of their own district, and in later years all the great successes in the Caucasus, the Himalayas and the Andes, have been won under the leadership of these or their successors. How they were valued and held in affectionate regard by their employers, is testified in every book of mountain travel.

Many particulars of the development of Alpine climbing will be found in Dr. Coolidge's volume, and the lists given in its pages show the large number of great peaks scaled and difficult passes crossed during the last five-and-fifty years, so that further details are needless. Two changes, however, in the character of Alpine climbing may be briefly noticed. With some of its younger votaries it has become more definitely a form of gymnastics. The older generation sought mainly to accomplish an ascent, and for that purpose adopted the most obvious and safe route; the younger often seems to prefer the more difficult and even the more dangerous. It sometimes incurs risks, which in earlier days would have been deemed hardly justifiable, with the result that accidents are less rare than formerly. Their number has been greatly increased (but for the most part outside the limits of our English Alpine Club) by the habit of climbing without guides. This, doubtless, has its attractions, and, when undertaken by men who are in vigorous health and have acquired experience from those already masters of the craft, is thoroughly justifiable; but even such men, if the expedition is likely to be long and difficult, should be more cautious in regard to bad weather than they would otherwise be, because they may find themselves involved in some unwonted peril. But guideless climbing is not for novices. The dangers of the Alps are real, and no little practice is required to recognise where they are latent. There are times when a single mistake may incur the penalty of death, either instantaneous—from the breaking cornice or the rush of an avalanche, from falling ice or stones—or after a lingering struggle with cold and hunger. Dozens of lives are annually sacrificed, especially among the Eastern Alps, by men who have plunged into difficulties with which they were incompetent to grapple; and the tale of death will continue to increase, unless it is more widely recognised that mountain climbing, as distinguished from mountain walking, requires not only a certain innate fitness, but also a preliminary training. For one or more guideless novices to attempt a difficult excursion is an act of presumptuous folly, but the risk is comparatively small to those who have learnt their craft; while an expedition in company with good guides does not, in my opinion, involve much more risk than a day's hunting to a man who can ride well to hounds. Death may come in either case; a falling stone or some other unexpected mischance may strike down the one, just as a horse's stumble, or mistake at a fence, may be fatal to the other. As the well-known nursery rhyme asserts, the children, if they had stayed at home, or been sliding on dry ground, would not have been drowned; but of what is not that true? Hardly any active sport or form of travel is without its attendant risks, and it is my deliberate opinion that those of mountaineering, as it was practised by the earlier members of our Alpine Club, are comparatively small, and that they are far outweighed by its rewards, such as the magnificence of the scenery, and the enhanced vigour imparted to body and mind.

One great change in Alpine travel has taken place within the memory of the present writer. Fifty years ago hardly any one dreamed of visiting the higher Alps before the spring was well advanced, or after the leaf had begun to fall. In the mountain valleys the inns often were not opened till some time in the month of June, and were closed in October, if not before the end of September. As was stated above, one or two daring climbers proved, before the Club was ten years old, that some glacier passes could be crossed even in the depth of winter, but they found few followers; partly, no doubt, because in many places food and lodging could not be obtained at that season. But a change was coming. Physicians began to ascertain that the old methods of treating pulmonary disease were in many cases erroneous, and that mischievous germs multiplied far more slowly in fresh air, even at a low temperature, than in warm and more or less stuffy rooms. Davos, about 1867, began to be frequented as a winter health resort for weakly, and especially consumptive, patients. After a time St. Moritz laid itself out for the reception of invalids, and before long the tonic virtues of the Alpine air in winter were generally appreciated. It was then discovered that the mountain regions at this season could be made

From a drawing by] [*Mr. Joseph Pennell.*

32. ON STEEP ROCKS.

To face p. 368.

not less attractive than in the summer to those still in full vigour. A rink had only to be constructed to secure skating as uninterrupted as in Canada. The toboggan was already in existence, though in a homely guise; the use of snowshoes was introduced from Canada and of skis from Scandinavia, so those who came in summer for lawn-tennis and golf returned in winter for the sports of that season. Year by year the number of visitors and of the hotels prepared for their reception increased, and certain centres are now said to be not less crowded in winter than they are in summer. Several years ago, when I was at Montreal in August, I was told, "But you should come and see us in December or January—that is our liveliest season." Most of my friends, excluding some enthusiastic climbers, say the same of the Alps. The cold is much more severe than in England, but with a sensible system of warming instead of the extravagant and almost useless open fires so dear to the British nature, it is not felt indoors; and outside it can be kept at bay with proper clothing. On a bright day also the heat of the sun is greater than in England, so that skaters often feel no need of an overcoat. There are now dozens of winter resorts at various elevations from about 2,500 to 6,000 feet above sea-level, greatly praised by those who frequent them. But of the Alps in winter I can hardly speak from personal experience. For many years past it would have been exceedingly difficult for me to leave England at this season, and I have so little love for the short days and the cold of winter that I have always doubted, since I am too old to become expert with skis and snowshoes, whether in my case "the game would be worth the candle." To myself no small part of the pleasure in a summer visit to the Alps is found on those delightful days when one lingers over the mountain flowers in walking, or sits for a time on some craggy bank to marvel at the beauties of the view. This in the winter would be impossible, and I doubt whether the great white pall spread over everything would not be a rather monotonous substitute for the "coat of many colours" which clothes the meadows and slopes in the summer season. Though I have never stayed in the Alps, I have twice passed through them in the winter, and the weather on one occasion was perfect. The higher parts, though more snow-clad than in summer, had not, as it seemed to me, gained in dignity. The valleys and lower slopes—all up to rather above the tree-limit—though the great sweeps of white possessed a certain solemn grandeur, were apt to be slightly monotonous, and where they were broken by crags presented contrasts rather too strong. There was great beauty in the snow-swathed spires of the pines; but the forests as a whole, where branches, bare by chance, seemed almost black from contrast, had a chequered aspect which was sometimes hardly pleasing; while the leafless larch branches, similarly contrasted with the white sheet from which they rose, seemed, if one may venture to say it, almost shabby.

One zone only of the mountains distinctly gained in beauty; that from about 6,500 to 8,500 feet above the sea-level; for it, in summer-time, is often without either the grandeur of the snowfields or the beauty of grassy alps and woods; it is bare, barren, almost dreary, a region where one is seldom tempted to linger—at any rate to examine the foreground scenery, because the sparse shrubs are stunted and ragged, the herbage is coarse, and the flowers are comparatively few. But in the winter this zone is shrouded in the purest white—a region of great undulations and domes of snow, such as we can find in summer two or three thousand feet higher up the mountains; for winter in the Alps, as in our English highlands, shows what their aspect may have been during parts of the Ice Age. Notwithstanding this, we must lose something; for at the present day much of the charm in the scenery of the High Alps is due to the passage from the varied colour and vigorous life of a temperate zone to the strong contrasts and solemn stillness of an Arctic region, and to the fact that, even when we have reached some commanding position among the Frost King's citadels, we can see that his realm is but an island in a wider world of colour, and growth, and life.

The greatly increased facilities for mountain travel, like railways of various sorts and motor-carriages, and the consequent large increase of visitors, have not a little marred the charms of the Alps. Some of their ill-effects have been already noticed, but one of a more general character may be mentioned in conclusion. The Alps have become, in a wider sense than that in which the phrase was once used, "The Playground of Europe," and suffer from the natural consequences. The tripper-tourist ravages the flowers, leaving as a substitute egg-shells and torn paper. It is not yet quite true to say of him, as of Attila's horse, that where it has trodden no grass will grow; but I am sure that some of the most interesting or beautiful Alpine flowers have become less common—at any rate, where tourists most do congregate—than they formerly were. The holly fern, with others which are rarities in Britain, the moss campion and the star gentians, the blue columbine, indeed, almost every plant conspicuous for the beauty of its flower, are perceptibly diminishing in number; while the edelweiss has been, in some districts, almost extirpated. Fortunately the Swiss, at any rate, have become alive to the mischief, and the digging up of rare plants is forbidden by law; sanctuaries are established for them, and a strong public opinion is growing up against this wanton destruction. We, who suffer in like way from the plunderers and the hooligans, emitted in floods from our larger towns, cannot but wish this movement health and strength. Time was, not so long ago, that protective measures—not for living things only—were greatly needed, for the advertisement had begun to penetrate into the heart of the mountains. Some twenty years ago I saw, in the higher part of the valley of the Reuss, that the owner of a chocolate factory in one of the Swiss towns had covered with paint to match the colour of his produce a particularly conspicuous boulder—I believe the one which plays a part in the legend of the Devil's Bridge—and had inscribed on it, in big white letters, the address of his place of business. Not only so, but on reaching the Bridge itself, I found that a large area on the wonderfully even surface of the cliff which rises so grandly on the left bank at that place, had been converted by the bill-sticker to his own uses, was painted red and inscribed with advertisements of hotels; while at the top of all was depicted a figure of the devil. "Very appropriate" was the comment which I wrote on this finishing touch, soon after I had seen it, and the time which has passed since then does not incline me to change my opinion.[1]

The Alps—may not the same be said of more than one other country?—are becoming vulgarised. To those persons who apparently regard dress and diversion, festivities and amusements, not as the exceptions, but as the rules of life, that may seem a trifling matter; but I fear that the words of Ruskin, who, more than most men, had entered into the spirit of the Alps, will be found too true: "Two years ago, when I was first beginning to work out the subject [of vulgarity] and chatting with one of my keenest-minded friends,[2] . . . I casually asked him, 'What is vulgarity?' merely to see what he would say, not supposing it possible to get a sudden answer. He thought for about a minute, then answered quietly, 'It is merely one of the forms of death.'" These words appeared in 1860, and I am afraid that, in the half-century which has passed since then, they have acquired a yet more ominous significance for more than one nation (not excepting our own) which claims to be a leader in civilisation; since, though there is much to justify hope for the future, there are also not a few symptoms which too closely resemble those portending the decline and fall of Rome.

[1] Since then a league has been formed for the Preservation of Swiss Scenery, which has already produced good effects, and a branch of it has been established in England. But we are far from being ourselves immaculate. The advertisement fiend does his best everywhere to mar the beauty of our own country.

[2] "Modern Painters," part ix. chap. vii.

APPENDICES

APPENDIX I

I HAVE stated in the Preface, as an excuse for maintaining my opinions on certain controversial points in Alpine geology, that they had not been hastily formed. Altogether I have visited the Alps thirty-five times, generally remaining from three to five weeks among the mountains, so that I must have spent nearer three than two years of my life among them. Besides this, I have six times merely passed through the chain on my way to or from Italy. The earlier journeys were mainly walking tours, in which much ground was covered; the later were more often spent at one or perhaps two centres. Almost from the first I studied the action of ice and other questions of physiography, but was not more interested than the ordinary geologist in the rocks of the Alps till about thirty-two years ago, when, after working for some few years with the microscope on petrological questions in Great Britain, I turned to the Alps in the hope of obtaining light on some of my difficulties, and in 1880 made my first journey with that purpose definitely in view.

The following list of my wanderings will show that I have seen most parts of the chain. (1) In 1856, during a summer spent with a reading party at Lausanne, I visited Chamonix and the Great St. Bernard. (2) In 1858 I had a long ramble in Central Switzerland, beginning at the Lake of Zurich, crossing from Zermatt to the Italian Lakes, and returning, after a visit to Venice, by the Simplon. (3) 1859. By the Gemmi to Zermatt, returning with some divergence by the Rhone Valley. (4) 1860. Through Dauphiné and the Viso district to Turin, thence by the Val Tournanche to Zermatt and Saas, and then to the Italian Lakes, returning by the Lepontine Alps to the Vorder Rhine and Glarus district. (5) 1861. By the Gemmi to Zermatt, thence by the Val d'Aoste to Courmayeur and the Italian Lakes, returning by the Splügen. (6) 1862. In the Tarentaise, Graians, and Dauphiné. (7) 1863. In Dauphiné, the Maurienne, and the Graians, returning by the Great St. Bernard. (8) 1864. From the Lake of Geneva by a mountain route *viâ* Chamonix, Courmayeur, and along or near the crest of the Alps to the southern side of the Dauphiné peaks, thence by La Mure and Laffrey (Napoleon, 1815) to Grenoble. (9) 1865. In the Savoy Alps and Western Oberland. (10) 1867. To Pontresina by the Albula Pass; thence by the Val Viola and Stelvio to Trafoi, Botzen, the Pusterthal and the Cortina district, returning by the Brenner. (11) 1868. Zigzag route in Glarus Alps to Coire, thence to Pontresina, the Ortler district, and Western Tyrol, returning by the Achensee to Munich. (12) 1870. In the Oberland. (13) 1872. The Brenner to Botzen; through the Dolomites to Lienz, and "across country" to Salzburg; the Salzkammergut. (14) 1873. By Arlberg and upper valley of Inn to Pontresina; thence by the Italian Lakes along southern valleys of the Pennines to Zermatt and Val d'Hérens. (15) 1874. By Western Oberland and St. Luc to Zermatt, leaving by Val d'Hérens. (16) 1875. About the Pennines between

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Zermatt, Courmayeur, and Chamonix. (17) 1878. Italian Lakes and St. Gotthard (halts on return from Italy). (18) 1880. To Pontresina by Albula Pass; thence south of the Bernina and eastward by the Adamello district to the Dolomites, returning by Brenner. (19) 1881. Saas district; Simplon, excursion to Lago Maggiore; Eggischhorn, and Belalp. (20) 1883. Lepontine Alps and Belalp. (21) 1885. Across the Alps from Maderanerthal to Italian Lakes, returning by Great St. Bernard, Champery, and Sixt. (22) 1887. Across the Alps through Dauphiné and through the Tyrol, from head of Pusterthal to Kitzbühel; approaching by Lago di Garda and Trent, and returning by the Inn valley and Arlberg. (23) 1889. Lepontine Alps and Zermatt. (24) 1891. To Lepontine Alps by the Grimsel, and then to Saas district; excursions from Rhone valley on return. (25) 1893. Lepontine Alps. By Bernardino Pass to Coire and Pontresina, returning *viâ* Davos. (26) 1895. By Gemmi Pass to Zinal, returning by Grimsel. (27) 1896. District about Splügen, Bernardino, and Lukmanier Passes, returning by the St. Gotthard. (28) 1897. Val Piora and Lower Haslithal. (29) 1900. Arolla; halts in Rhone valley. (30) 1901. Saas district. (31) 1902. By St. Gotthard, Orta, and Biella, to Val d'Aoste and Cogne, returning by Little St. Bernard. (32) 1903. Val d'Anniviers. (33) 1905. Saas district. (34) 1907. Saas district and Val d'Ossola. (35) 1911. Airolo and Grindelwald.

In the course of these travels I have made, not reckoning walks without any special aim, about 110 definite ascents, 65 of them up to or above 10,000 feet, and have crossed, almost always on foot, more than 170 passes, 36 of them above that altitude, so that, as my ramblings have extended from the Viso to the Salzkammergut, I may claim to have acquired a fair knowledge of the chain. On some of these journeys I was alone; on four I was with near relations, who could not undertake laborious excursions; in more than half I fortunately had travelling companions. Of them, I regret to say, death has deprived me of W. and G. S. Mathews, R. W. Taylor, and E. Walton; but there still remain J. C. Hawkshaw, W. G. Adams, J. Parkinson, J. Eccles, and E. Hill, the comrade of several journeys, beginning with 1880. To the last-named three I am indebted for much help in working out geological questions.

The following is a list of my papers dealing with Alpine physiographical or petrological questions[1]:—

On the Formation of Cirques. Q.J., 1871, p. 312.

Lakes of the North-Eastern Alps, and their bearing on the Glacier-Erosion Theory. Q.J., 1873, p. 382.

Notes on the Upper Engadine and the Italian Valleys of Monte Rosa, &c. Q.J., 1874, p. 479.

Some Notes on Glaciers. G.M., 1876, p. 197.

On Mr. Helland's Theory of the Formation of Cirques. G.M., 1877, p. 273.

On some specimens of Gabbro from the Pennine Alps. M.M., 1879, p. 5.

On some Serpentines from the Rhætian Alps. G.M., 1880, p. 538.

On a supposed case of Metamorphism in an Alpine rock of Carboniferous Age. G.M., 1883, p. 507.

Note on the Nagelflue of the Rigi and Rossberg. G.M., 1883, p. 511.

[1] The following abbreviations are used in the references:—A.J. = Alpine Journal. B.A. = British Association. G.J. = Geographical Journal. G.M. = Geological Magazine. M.M. = Mineralogical Magazine. G.A. = Geologists' Association Proceedings. P.M. = Philosophical Magazine. Q.J. = Quarterly Journal of Geological Society. (Some of the titles are condensed.)

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Presidential Address to Geological Society. Q.J., 1886, p. 49 (proc.).
On a Glaucophane Eclogite from the Val d'Aoste. M.M., 1887, p. 1.
On a variety of Glaucophane from the Val Chisone. M.M., 1887, p. 191.
Origin of Banded Gneisses. G.M., 1887, p. 573.
Rounding of Pebbles by Alpine Rivers. G.M., 1888, p. 54.
Notes on two Traverses of the Crystalline Rocks of the Alps. Q.J., 1889, p. 67.
On the Crystalline Schists and their Relation to the Mesozoic Rocks in the Alps. Q.J., 1890, p. 187.
The Effects of Pressure on Crystalline Limestones. G.M., 1889, p. 483.
Note on the Effect of Pressure upon Serpentine in the Pennine Alps. G.M., 1890, p. 533.
Petrological Notes on the Euphotide of the Saas-thal. P.M., 1892, p. 237.
Growth and Sculpture of the Alps. A.J., vol. xiv., pp. 38, 105, 221.
On the so-called Gneiss of Carboniferous Age at Guttannen. Q.J., 1892, p. 390.
Do Glaciers Excavate? G.J., 1893, p. 481.
Note on the Nufenenstock. Q.J., 1893, p. 89.
On some Schistose Greenstones and Allied Hornblende Schists. Q.J., p. 94.
On a Secondary Development of Biotite and Hornblende in Crystalline Schists, &c. Q.J., p. 104.
On some Quartz-schists from the Alps. G.M., 1893, p. 204.
Some cases of the Conversion of Compact Greenstones into Schists. Q.J., 1894, p. 279.
Mesozoic Rocks and Crystalline Schists in the Lepontine Alps. Q.J., 1894, p. 285.
Some Notes on Gneiss. G.M., 1894, p. 114.
On an Alpine Nickel-bearing Serpentine with Fulgurites. Q.J., 1896, p. 452 (with E. Aston).
On a Pebbly Quartz-schist from the Val d'Anniviers. G.M., 1896, p. 400.
The Kirchet and its Critics. A.J., 1897, p. 29.
Additional Note on Sections near Summit of Furka Pass. Q.J., 1897, p. 16.
Note on an Ovenstone (Talcose-schist) from near Zinal. G.M., 1897, p. 110.
Outline of Petrology and Physical History of the Alps. G.A., 1897, p. 1.
Garnet-actinolite Schists on Southern Side of the St. Gotthard Pass. Q.J., 1898, p. 357.
Some small Lake-basins in the Lepontine Alps. G.M., 1898, p. 15.
Plant-stems in the Guttannen Gneiss. G.M., 1900, p. 215.
Schists in the Lepontine Alps. G.M., 1901, p. 161.
Alpine Valleys in Relation to Glaciers. Q.J., 1902, p. 185.
Moraines and Mud-streams in the Alps. G.M., 1902, p. 8.
The Magnetite Mines near Cogne. Q.J., 1903, p. 55.
Microscopic Structure of Serpentine-forming Minerals, &c. (including Alpine). Q.J., 1905, p. 690 (with Dr. C. A. Raisin).
Southern Origin of Northern Zone of Savoy Alps. Q.J., 1907, p. 294.
Antigorite and the Val Antigorio. Q.J., 1908, p. 152.
Presidential Address (on Icework). B.A., 1911, p. 3.

APPENDIX II

Notes on the Full-page Illustrations

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2. Mont Blanc and Aiguilles des Charmoz. A characteristic illustration of the scenery of the Slaty Crystallines (protogine more or less fissile). See page 93.
3. Dolomite Peaks from the Marmolata. The Antelao is on the left; in the centre (nearer) the Civetta; on the right the Pelmo. Illustrates the scenery of this variety (Dachstein Dolomite) of the Compact Coherents. See pages 23, 99.
4. View from Froppa Glacier, Marmarola. Another characteristic view of Dolomite Peaks. Page 102.
5. Northern side of Aiguilles des Charmoz. This point of view brings out even more strongly the splintered aspect of the Slaty Crystallines. See pages 93–96.
6. The Wetterhorn near Grindelwald. A very characteristic example of the scenery of the Compact Coherents (limestone). See page 81.
7. The Cinque Torre. The Dolomite rock in a far stage of ruin. See page 101, where the woodcut is from a sketch made by myself in 1867.
8. The Drei Zinnen. One of the most striking examples of the "ruined fortress" character of this variety (Dachstein Dolomite) of the Compact Coherents. See page 100.
9. Bergschrund of a glacier. A very characteristic example from near the Col du Géant. Pages 106, 134.
10. Upper snowfields of the Ortler. Shows the bergschrund at the foot of the steep snowslopes which rest on the ridges of rock. The track of the travellers can be seen rather below it. If my memory is correct (after forty-five years) the summit of the Otler appears on the right. See page 106, 111.
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25. Avalanche on the Wetterhorn. This view, taken on the way to the Great Scheidegg from Grindelwald, represents one of the comparatively small avalanches which may be seen on this mountain and still more frequently on the Jungfrau. The avalanche, about the middle of the cliffs, looks like a small waterfall. See page 221.
26. The Märjelen See. The photograph was taken about four years ago. See page 229.
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I am indebted to the kindness of the following friends for photographs reproduced in this volume. For 1 (Frontispiece), 11, 17, 21, 26 to Mr. J. J. Lister, F.R.S.; for 5, 9, 12, 13, 16, 18, 19, 20 to Dr. Tempest Anderson, F.G.S.; for 6 to the Rev. T. C. Fitzpatrick, President of Queens' College, Cambridge; for 22 to Mr. J. Eccles, F.G.S. (and to Messrs. Kegan Paul & Co. for a cliché of the block); for 23 to Prof. E. J. Garwood. I have also to thank Mr. E. T. Compton for illustration 27; Mrs. Aubrey Le Blond for 10, 14, 15, 25, 31; and Mr. T. Fisher Unwin for 2, 3, 4, 7, 8, 24, 28, 29, 30, 32.

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